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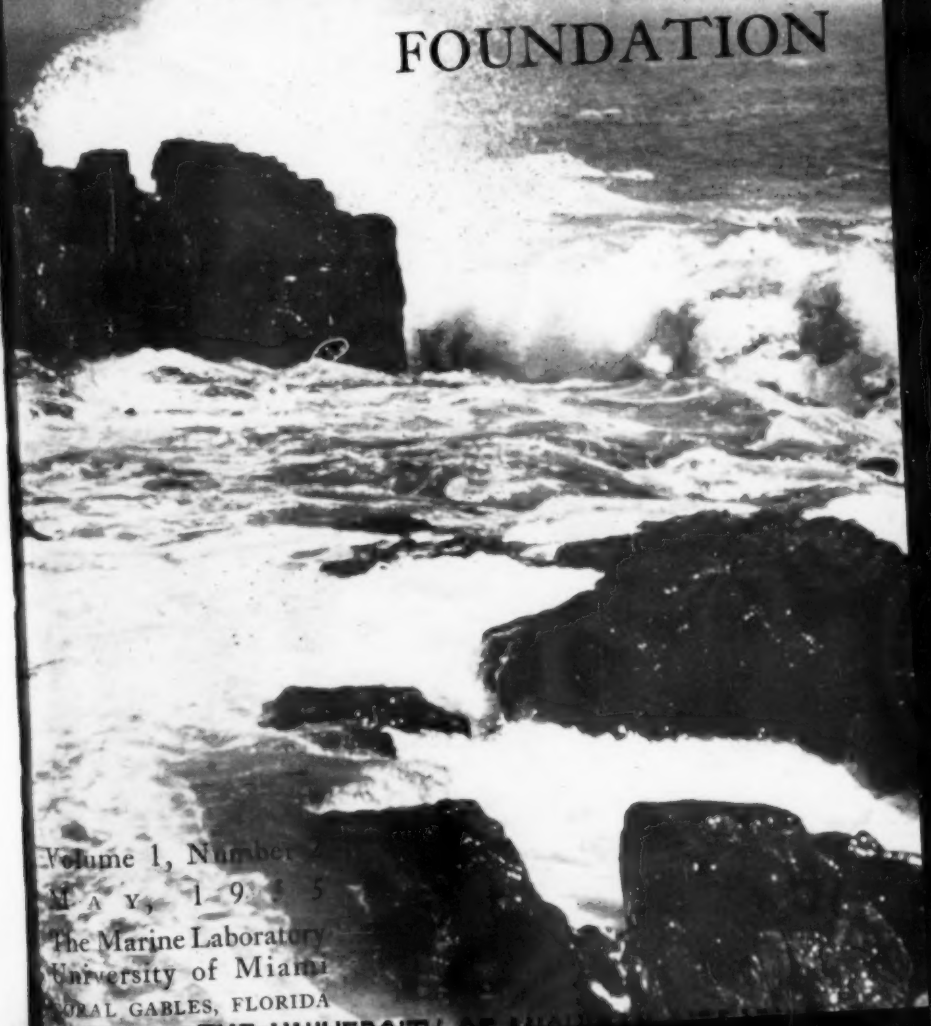
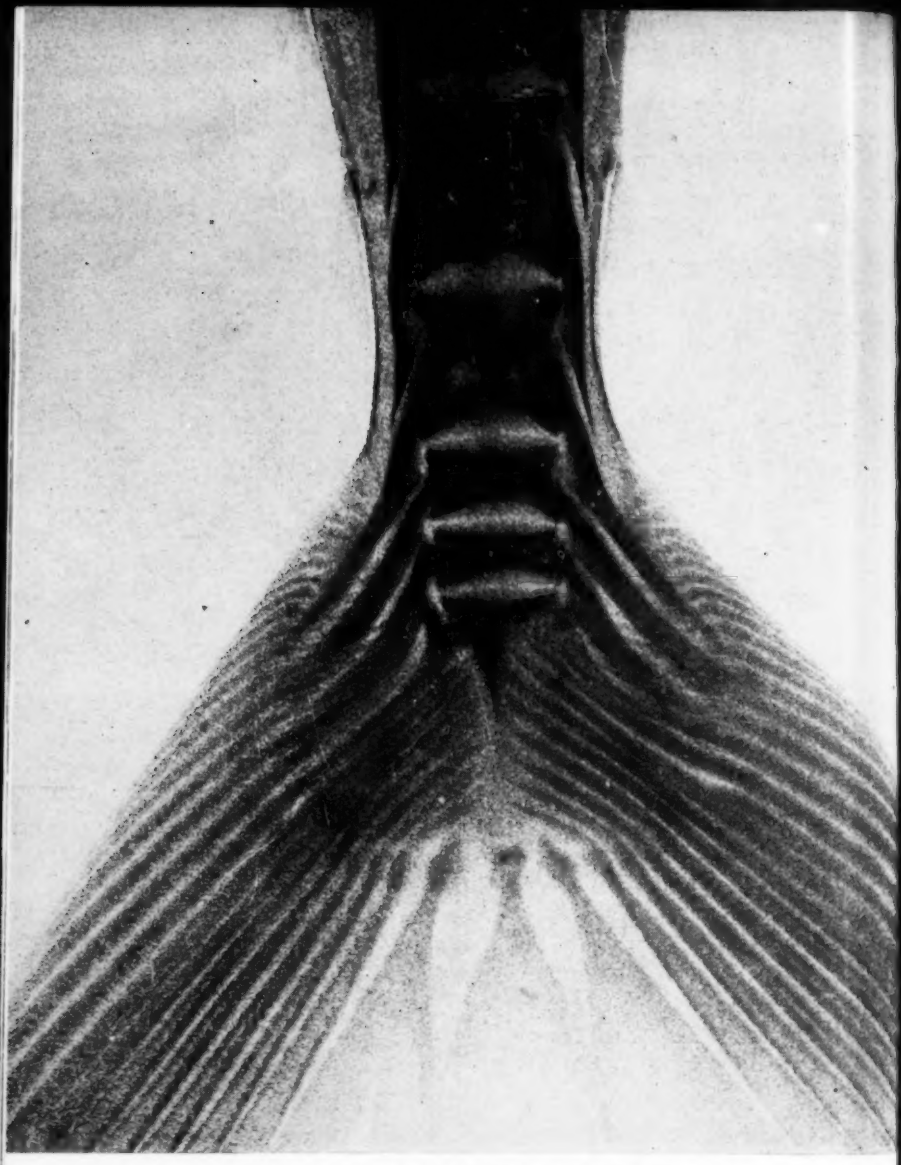
Bulletin OF THE INTERNATIONAL Oceanographic FOUNDATION



Volume 1, Number 2
MAY, 1945
The Marine Laboratory
University of Miami
CORAL GABLES, FLORIDA

THE UNIVERSITY OF MIAMI



FOR THE STORY *behind this photograph see page 40.*

BULLETIN of the
INTERNATIONAL
OCEANOGRAPHIC
FOUNDATION

Editorial Office: The Marine Laboratory, University of Miami, Coral Gables, Fla.

34-39-220

AN ANALYTICAL CHEMIST *from Miami checks Red Tide water.*

What Is Research?

By F. G. WALTON SMITH

MUCH HAS BEEN WRITTEN in recent years of the need to seek more food and mineral resources from the ocean. Much more could be written about the part which the ocean already plays in the complex civilization in which we now live, its relations to weather, to transportation, and, indirectly, to food, oil and mineral exploration and discovery, to mention only a few of the ways in which we are tied to the seas. But in all of these the stress has been upon the application of scientific knowledge to immediately useful purposes and today it is too often taken for granted that this knowledge itself will always be forthcoming. It may therefore come as a surprise to those not closely concerned with scientific research to know that in this country, in spite of its rapid growth, scientific investigation has suffered from a deficiency which threatens the very thing that is most taken for granted—the eminence of the United States in the world of science.

The Origin of Industrial Greatness

The outstanding technological developments of the electronic age, television, radio, mechanical brains, antibiotics and washing machines, all of these are evidences of America's leadership, but they are the end products of basic discoveries made elsewhere. They are based upon, and have been developed from, the source materials of fundamental science, the discoveries made by scientists who seek only to extend the boundaries of knowledge. The point is well illustrated by the apparently useless investigations of Nils Bohr and his successors, who explored the irregularities of atomic structure and behaviour, with no

thought that such "theoretical" concepts could ever lead to the development of atomic energy with all its potentials for good, as well as evil. It is even better illustrated, possibly, by the early work on electromagnetic waves, dismissed by the Royal Society as of minor theoretical interest and of no practical importance—though later to become the foundation of the whole vast field of applied electronics.

To most people, scientific research today has come to mean more and more the end results and applications, the machines and industrial processes, the mechanical kitchen devices and the speed of air travel. But, if we look behind this glittering facade, we find that, beyond the engineers and draftsmen, beyond the designers, the echelon of applied scientists, there is a store of basic scientific knowledge upon which it is all based, and behind this the fundamental scientist whose work is prompted by disinterested intellectual curiosity alone rather than by a desire to make "useful discoveries." This is the ultimate source of all technological development. It is the failure to realise this and to make proper provision for replenishing the store of basic scientific knowledge that is slowly beginning to be recognized in the United States. One of its symptoms is the high proportion of "project" research within our universities.

By its very nature, pure scientific enquiry can only be accomplished in an atmosphere where competent and imaginative scientists are able to explore at will. Since the results are not known, the direction cannot be rigidly predetermined. And yet the great bulk of research in our universities today is "project" work, in which at least a strong hint of the expected result is present. It is a subsidisation of projects and not of scientists. For the most part government funds spent in the universities go to support applications of science rather than basic research. The financing of projects rather than of brains is not conducive to the best scientific development and instead tends to encourage scientific hacks and mediocre institutions—a huge number of followers but few leaders, too much experiment and too little thought.

Alfred P. Sloan, board chairman of General Motors, speaking in January, made it clear that industry, or at least a substantial representation of industry, is fully aware of the situation. "We in this country — and I think what I will say is generally agreed upon—are not doing the basic research we ought to do in support of our applied research and our advance engineering. We have got to expand our facilities for basic research. For some reason or other we have not been able to fire the imagination of our able young men and women to devote their lives to basic investigation. We must do a better job in that particular."

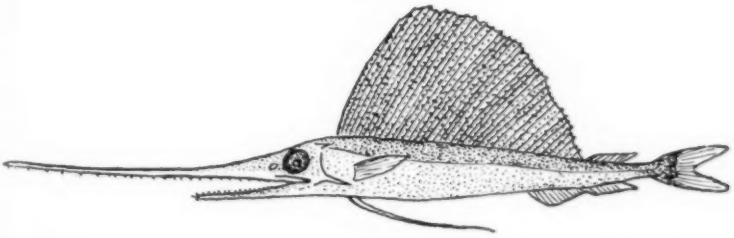
Fortunately there are elements of optimism in the picture. Mr. Sloan, having pointed out the failure of a large part of industry to support fundamental science, has taken an important step towards correcting it. The foundation named after him now has under consideration a broad new program for the promotion of research in the basic sciences. It is also noteworthy that the current series of articles on "The New Economy" in FORTUNE magazine includes an article in which Eric Hodgins, referring mainly to the physical sciences, brings the matter into sharp focus.

Neglect of The Ocean

What has this to do with the oceans and with the marine sciences? In the first place, although the greater part of the earth's surface consists of ocean, although the bulk of all food materials grow in the ocean and although the ocean is a great storehouse of every mineral element, yet the scientific endeavour so far expended upon it is unbelievably small compared to what is spent upon the dry land sciences. Moreover, in common with all science in America today, most of the work carried out is "project" research. It is this lack of balance between subsidizing individual brains and subsidizing projects that must be redressed.

There is, of course, a place for project investigation, studies directed to a specific and closely defined objective. The danger is that fundamental investigations will not receive their proportionate attention, because of the more immediate appeal that "useful" research has. It is here that such organizations as the International Oceanographic Foundation, acting for private and industrial participants, may be able to help by setting up financial provision for a vigorous growth of disinterested scientific enquiry, the necessary basis for the practical developments of the future. Already both private sponsors and industrial associates have begun to set up funds within the Foundation which are aimed at broad fundamental fields of study rather than at specific projects.

The future outlook, once the problem is recognized, will be increasingly improved. As Dr. Vannevar Bush stated in the *Carnegie Report for 1953:* ". . . there may be men among us, highly successful in affairs, anxious to serve humanity, who will wish to look at the skies, or delve into the earth, or probe for the secret of life, not because it will add to the comforts or reduce the hazards of existence but because it may render us a more dignified and understanding race with greater satisfaction in living. If so there will be more and greater institutions devoted to the search for knowledge for its own sake." If we substitute "plunge into the seas" for "delve into the earth", this could well apply to the future of oceanography and so, indirectly, assure us of a future in which the oceans will give us their greatest yield.



YOUNG WESTERN ATLANTIC SAILFISH *from the Gulf Stream off Florida, about three inches long.*

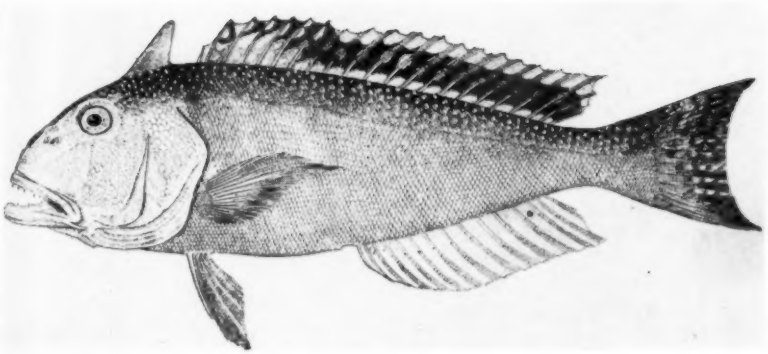
The Mystery of the Tilefish

By DONALD DE SYLVA

EARLY ONE MORNING in March, 1882, a ship's captain rubbed his eyes and peered unbelievingly across the foggy waters off Delaware Bay. For as far as he could see were miles and miles of dead and dying fish. Upon closer examination he discovered that they were nearly all the same kind, the tilefish. Many other boat captains were arriving in Philadelphia, New York and Boston with the same story: each had seen hundreds of thousands. To the uninitiated, it must have seemed amazing that there were that many fish in the ocean. When all the accounts were pieced together it was estimated that in an area from 5000 to 7500 square miles at least a billion and a half dead tilefish were sighted.

What caused such a disaster? What possible force could so quickly and so completely wipe out these tremendous numbers? To reconstruct what probably had happened it is first necessary to go back to 1879, when a cod fisherman caught the first specimen of tilefish off Nantucket Island in 150 fathoms of water. Others were caught nearby, and soon it was found that they were plentiful enough to support a lucrative new fishery. Its quality was excellent, and soon a sizeable market was established.

The fishermen had noted that these fish could only be caught at certain places and at certain depths. Their keen observations were not to be discounted, for scientists soon confirmed them. It became obvious that the tilefish had very strong preferences for certain locations. They could only be caught along the upper part of the continental slope and on the outer edge of the shelf. The shelf is the area of relatively shallow water which rims the continent. At the outer edge of this shelf is the continental slope, which rapidly descends to the ocean depths. It is at the junction of the slope and the shelf that a tongue of relatively warm Gulf Stream water, roughly between 47° and 53°F., bathes the fishing grounds. This tongue varies only a few degrees in temperature from season to season, and apparently the tilefish existed in this region in a delicate balance with their surroundings. Any increase or decrease in temperature would be unsuitable to the fish and would cause them to seek out new territory, with suitable temperature. But temperature is not the only thorn in the tilefish's side. Apparently its movements also depend upon the depth of the water, and although it can be taken occasionally in 170 fathoms, it is mostly caught in 45 to 100 fathoms, very close to the bottom. The tilefish must remain within these temperature and depth ranges to survive. When the surroundings change, an animal must either adapt itself to the new surroundings, migrate to another region, or perish. Unfortunately, at least in this respect, most sea life is completely molded to its surroundings, so that it cannot adapt, except within relatively narrow limits. Therefore, it must migrate from a zone which becomes unfavorable to a new area. In this case, the movements of the tilefish appear to be rigidly controlled on one



THE TILEFISH *which disappeared from its accustomed haunts after a disastrous mortality in 1882.*

hand by temperature and on the other by depth. Thus, the most suitable temperatures, i.e., 47-53°F., usually occur at depths between 45 and 100 fathoms, or possibly greater. Fortunately these depths are suitable to the fish. But when the favorable temperatures are at shallower or greater depths, the tilefish would not be able to find the right combination of temperature and depth. It follows that if something were to happen which would rather suddenly change this environment the tilefish would have to seek out this relatively peculiar habitat or else perish with the change in surroundings, and it is improbable that such a sluggish fish could migrate out of this unfavorable area very quickly.

And so it was that during the month of March, 1882, tragedy befell the tilefish. No one knew at the time exactly what had happened. Various reasons were proposed for this gigantic catastrophe, but it was generally believed by scientists that something had occurred which had dislodged the fish from its narrow temperature and depth ranges. While no bottom temperatures had been taken over the tilefish grounds when the mortality occurred it was noted that by the end of the following August the bottom temperatures were 48-49°F, as compared with the usual 50-52°F., which indicated that the temperature had possibly been much lower earlier in the year when the mortality occurred. It was postulated, therefore, that an unusually strong wedge of cold water from the Labrador Current had pushed itself further south than in previous years, possibly due to unusually heavy storms during that winter which might have disturbed the delicate environment of the tilefish. These cold, dense waters had swept along the bottom and had partially displaced the northern edge of the warm Gulf Stream, and the tilefish, being somewhat sedentary in their habits, were not able to vacate the cold region fast enough nor were they able, because of physiological depth restrictions, to move to shallower or deeper waters to escape this aquatic cold front. That other species of fish had also been affected was shown the following summer by their absence in a number of dredge hauls.

Furthermore, other types of sea life that had characterized this warm zone during previous years had now disappeared.

Following the mass mortality of 1882 numerous scientific explorations failed to disclose the presence of a single tilefish. Oceanographers predicted the return of the tilefish with normal temperature conditions, however, and in 1892, eight tilefish were caught off Martha's Vineyard and fifty-three were subsequently taken in 1893. After a lapse of four years, tilefish were again picked up in deep water south of Martha's Vineyard. The catch fluctuated considerably for a number of years but in general remained at a low point. Finally, by 1915 the U.S. Bureau of Fisheries began an intensified marketing program with the belief that the tilefish was once again present in sufficient numbers to support a fishery. The demand was high and by 1917 over 11,000,000 pounds had been caught. Unfortunately this market demand waned until, in 1947, only 441,000 pounds were landed. Today there is every indication that the tilefish fishery could be greatly expanded if the demand warranted its exploitation.

It is interesting to note that tilefish have been caught in recent years off the east coast of Florida and in the Gulf of Mexico. These fish are believed to belong to a separate population from those found off New England. On the east coast, they have been taken from Miami southwards, and in the Gulf they are caught at Key West, Dry Tortugas and Campeche Banks, all at about the 100-fathom curve. These are mostly of larger sizes, ranging up to 35 pounds. In the Miami area there appear to be four separate congregations of tilefish which can be found in approximately the same area during the greater part of the year. However, one of these assemblages is composed of small fish, from five to ten pounds, which can be caught in less than 200 feet of water (about 33 fathoms), a depth shallower than any recorded for the tilefish off New England.

The disappearance and reappearance of the tilefish was an enigma which was finally explained by a study of the medium in which the fish lives. Its disappearance might have been predicted had adequate study been made of its surroundings beforehand. Perhaps scientists would have been able to locate tilefish sooner than they did or even locate new populations, such as exist off Florida and the Gulf of Mexico, by making use of the knowledge of its surroundings. More than ever before scientists are realizing how closely aquatic organisms are adapted to the surroundings, and researchers are directing their studies from the animal itself to its habitat in order to determine why the animal behaves as it does. The science of oceanography studies this environment and the observations obtained are useful not only in explaining some of the ocean mysteries such as the tilefish disappearance, the Red Tide, and the disappearance of the California sardine but also in the utilization of chemical and physical data in ocean exploration. It is this basic information about the surroundings of an animal that will one day permit us to locate new and potential food sources for the world.

Tarpon Research

A FUND FOR supporting research on tarpon has been inaugurated by Mr. Roger S. Firestone. The Gamefish Research Committee of the International Oceanographic Foundation is hopeful of adding to this fund in time to commence the research work sometime in May or June of this year.

For many years Mr. Firestone has been interested in the tarpon because of its beauty and the strong and exciting battle it gives the angler when hooked. Like many other salt water anglers, he has reached a point in his admiration for the gamester where he desires to know more about it. He feels, too, that other anglers who have experienced the thrill of fighting a hooked tarpon may likewise be interested in supporting a study of this magnificent game fish.

As late as the early 1880's it was deemed impossible to catch a gamester weighing more than 100 pounds on rod and reel, one oldtimer actually expressing the opinion that a 100-pound salt water fish could not be taken with any sporting tackle then available. This idea was exploded during the winter of 1884 when Samuel H. Jones of Philadelphia, Pa., hooked, fought and boated a 172½-pound tarpon in the Indian River Inlet on the east coast of Florida. The finster measured seven feet, four inches in length.

Prior to that catch, one angler put in writing his opinion that big tarpon were practically impossible to land on rod and reel. Another angler offered

THE PICTURE BELOW *illustrates better than words can tell the amazing speed of a striking tarpon. The fish has struck at a cast plug (note small circle of water ripple.) After diving beneath the surface with the plug in its mouth it has leaped clear of the water (note large circle) and thrown the plug, which in this instance contained barbless hooks. All this has happened in such a short space of time that the water ripples made by the line, both when the tarpon struck and when it leaped, are still plainly visible!*

a free railroad ticket to Florida and three months' room and board at a hotel for anyone catching one of these gamesters. Whether or not anyone collected on this offer is not recorded, but the fact remains that Angler Jones did fight and boat the 172½-pounder, and it was not long before other anglers were journeying to Florida and having the piscatorial time of their lives seeking the mighty Silver King.

First of Big Game Fishes

Thus it might be said, in truth, that the tarpon was the original big game fish and that all other big game fishing, even for the giant tuna, the marlins and the broadbill swordfish, traces back to the impetus given by the tarpon. To this day, the tarpon holds a place dear in the hearts of salt water anglers, vying with the sailfish in popularity. That it deserves this niche no one who has hooked this leaping gamester will deny.

Despite this popularity and the knowledge anglers and their guides have gained of the tarpon, scientifically speaking very little is known about it. Where and when do tarpon spawn? How many eggs are contained in the average tarpon roe? What is the rate of growth following the hatching of tiny baby tarpon? What enemies do the tarpon have? Of what does the tarpon diet consist in the larval state and throughout the life of this fish? Why do tarpon tend to go into fresh waters at certain seasons of the year? How do they manage to live in fresh water through long periods of time?

These and many other questions will be answered by the proposed research, and through the knowledge gained the scientific world and the world of anglers will be enlightened. This knowledge will owe much to the founder of the tarpon research fund, Mr. Roger Firestone, and to the others who may contribute to it. It will be a monument to the memory of Angler Jones, who caught the first tarpon on rod and reel. Best of all, it will be a well-deserved tribute to a game fighting fish that enabled salt water anglers to view new horizons—the gamester that put salt water angling on a sporting basis, awakened interest in things piscatorial throughout the world and is still gaining adherents by the thousands annually.

The Voyage of The Beagle

By ROBERT M. INGLE

ON THE 27TH DAY of December, 1831, Her Majesty's Ship *Beagle,* a ten gun brig, sailed from Devonport, England. Although the moment of departure was inauspicious (she had twice put to sea only to be driven back by heavy southwest gales), later events were to identify the voyage as one of the most important ever made.

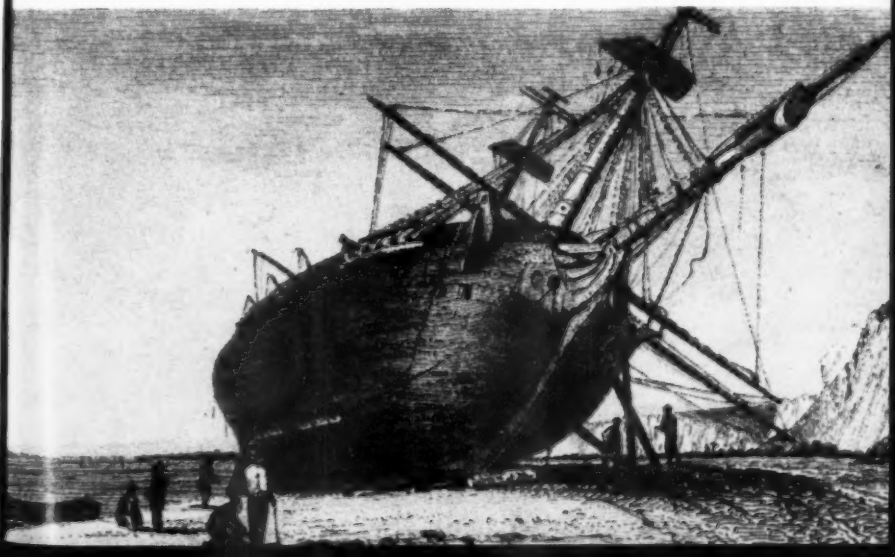
The expedition was intended simply to continue certain explorations at the southern tip of South America which had been started during an earlier trip in 1826. Also the present trip was to proceed across the Pacific and home by way of the Cape of Good Hope, primarily to carry a chain of chronological measurements around the world.

For making certain routine observations on the plants, animals and geological formations encountered, the Admiralty had installed on board an unknown young biologist, still in his early twenties, named Charles Darwin.

Strange sea-dust

Three weeks after leaving England, the *Beagle* dropped anchor in the Cape Verde Islands off the west coast of Africa (Dakar). There Charles Darwin collected some of the dust which so commonly filled the air of the entire region. Later this fine material which had fallen so profusely over the ship was sent to scientists in Europe, where it was shown to consist of the *skeletons of microscopic animals.* Although it was later shown to have originated in Africa and carried to the Cape Verde area by wind, none of the species identified were native to Africa; but, for some unknown reason, two of the species whose skel-

H.M.S. Beagle, laid ashore, River Santa Cruz, Patagonia.



etons fell on the *Beagle* were native to South America.

Collections and observations were made of the native marine animals and the *Beagle* proceeded southward across the Atlantic to St. Paul's Rocks, about 540 miles from the eastern coast of what is now Brazil. So small that some modern atlases fail to note their existence, these tiny protuberances are less than three quarters of a mile in circumference with a high point of 50 feet above the sea.

After stops at Rio de Janeiro and Rio La Plata, the *Beagle* anchored on July 26, 1832, at Montevideo. There for two years the ship was engaged in surveying the extreme southern and eastern coasts of South America. Most of Darwin's studies during this period were carried out on land, but even so he ran into some very odd happenings at sea.

Seagoing Beetles

On one occasion, after leaving La Plata, the *Beagle* sailed through miles of butterflies, far at sea. They were very numerous and colored the air as far as the eye could reach. Once, while towing a roughly made net of fine mesh through the water, Darwin brought up a considerable number of beetles. This was a remarkable finding as insects are notoriously rare in salt water, even along coasts, and this was 17 miles from the nearest land.

Darwin considered that they were fresh water aquatic species that had been brought to salt water by a coastal stream, but, even so, their presence alive where found was an oddity. This compares with his capture of a wind blown grasshopper 370 miles to leeward of the coast of Africa, near the Cape Verde group.

Darwin discovers Red Tide

Off the coast of Chile, the *Beagle* passed through water of an entirely different color from the dark blue usually associated with the sea. With typical ingenuity, Darwin very carefully checked the water with a prim-

Charles Robert Darwin

itive microscope and thereby provided one of the first scientific reports on Red Tides, or poison water.

From his journal entry, we can easily see that the discolored water was caused by a mass blooming of dinoflagellates, the same type of small organism which has been shown to cause Red Tides and great fish mortality off the west coast of Florida.

The Galapagos Islands

By the 15th of September, 1835, the *Beagle* had finished all assigned chores in Chile, Peru and Tierra del Fuego and had sailed up the west coast of South America to the site of one of Nature's most magnificent and

challenging experiments—the Galapagos Islands. Lying about 500 miles west of Ecuador, right on the equator, the Galapagos present a panorama of emergent evolution in a small isolated group of islands surrounded by the vast Pacific ocean.

In relatively recent times, geologically speaking, blue oceanic waters covered what is now the Galapagos archipelago. Then, a series of volcanic eruptions raised pinnacles above the sea floor. Some of these rose above the level of the waves to establish a new island system.

As the centuries passed, a few animals and plants carried by capricious currents and winds colonized the remote and formidable rocks. From these few itinerant visitors there has evolved in the Galapagos an entirely new and different series of species.

Birth of Darwinian Evolution

Darwin was fascinated. After he reflected on his observations in the Galapagos, we find in his journal for the first time such expressions as "creative force," "acquired and rendered hereditary," and "acquired hereditary knowledge." Vague as his ideas were, they give a hint of what was to become, twenty years later, a thesis that would shake the foundations of the scientific world. It should be remembered that at the time of Darwin's visit to these islands, the idea that all species of animals and plants were made at the time of creation and that none had changed materially since had never been seriously questioned. Small wonder that this young man found the evidence before him difficult to interpret.

After Galapagos the doughty little *Beagle* started a 3200 mile trek across the vast Pacific. With trade winds at her back she made during much of the voyage about 150 miles a day.

TAHU ATA, *a typical coral formation*

The origin of coral reefs

Very soon Darwin viewed for the first time the coral atolls of the South Pacific. He was surprised and intrigued by the circles of coral rock rising slightly above the surface of the sea, encircling tranquil lagoons.

Atolls had long puzzled mariners. What strange forces of nature created these doughnut shaped islands in the Pacific vastness?

Modern geologists do not entirely agree with all of Darwin's minor points, but the general theory he proposed is still considered valid. He visualized mountains pushed up from the floor of the sea. Each of these mountain peaks would constitute a small island. Along the shores around

the island, coral grew. Then there was either a raising of the sea level or a sinking of the sea bottom which very slowly pulled the mountain-island under the waves. The material of which it was made easily disintegrated and washed away. But this disappearance of the land was so gradual that the corals were able to grow upward at a similar rate of speed until all that remained to mark the position of the mountain peak was the low ring of coral just beneath the sea. Where these corals broke the surface flotsam collected and small coral islets were found along the ring of the atoll. Thus, to Darwin, each atoll marks the presence of a submerged mountain peak.

From the South Pacific, the *Beagle* sailed leisurely around the Cape of Good Hope and, after another stop at Bahia, in Brazil, finally came home again. Charles Darwin disembarked on the 2nd of October, 1836, after having taken almost five years in circumnavigating the globe. One of the most unusual facts about the trip is that Darwin apparently never got over the chronic seasickness which dogged his days at sea.

This expedition was his last sally into the world. When he returned to England, partly because of chronic illness, his life was to stretch out through peaceful years of reflection and writing — the results of which were to shatter much of the existing scientific thought of the day. The publication of the *Origin of Species* in 1859 started an upheaval that quickly embroiled most of the literate peoples of the world.

In the United States of America controversy raged for years and culminated finally in the famous Scopes trial in Tennessee. There collided two of the greatest lawyers America has produced. The brilliant oratory of William Jennings Bryan rang out against teaching the theory of evolution in schools. The legal genius of the great defense attorney, Clarence Darrow, supported the opposing view —that evolution had been shown to exist and should be taught to the nation's children.

Although Clarence Darrow, and the cause he supported suffered a setback in Tennessee (Bryan won the court's decision) the theory gradually became generally accepted. In recent years new knowledge has permitted a few minor changes in Darwin's basic ideas but the theory of the survival of the fittest is today seldom questioned.

Thus, in a way, the voyage of the *Beagle,* though of minor interest as an oceanographic expedition, brought great fame to a young and perceptive scientist with the right kind of intellectual curiosity and ended in one of the most important theories of biology.

The Long Haul

By JOHN L. FARLEY, *Director*
Fish and Wildlife Service
United States Department of the Interior

Food for the Future

IN REVIEWING its programs for the conservation and development of our Nation's fishery resources, the Fish and Wildlife Service recently took a long look at the yield of food fish from the sea. The look extended twenty years into the future, to the year 1975.

By then, according to Service estimates, America's fast-growing population will have reached a stage where twenty-five percent more protein-, mineral-, and vitamin-bearing fish and shellfish will have to be drawn from the fishing banks, gulfs, open seas, and coastal waters surrounding our shores. This increase is essential, if our nutritional requirements are to be met. The present need is for 118,000,000 more pounds each year.

These additional fish and shellfish will have to be located and harvested —in existing fisheries and in the yet-to-be fisheries of tomorrow—if the sea is to play its traditional role as a good provider for mankind.

Although the commercial fisheries of the United States and Alaska yielded 4,700,000,000 pounds of fish and shellfish last year, this catch was considerably below the potential. Many factors influence the annual landings, but the Service has found that biological research, exploratory fishing, and gear development add up to a powerful three-pronged spearhead in any drive to increase the catch. These

SALMON *leaping Kittiwake Falls.*

LANDING *120 lb. yellowfin tuna. Mr. Hightower with gaff.*

three phases of the Service's work are being expanded to meet current and future needs.

Service specialists assigned to the Pacific Oceanic Fishery Investigations are at present vigorously studying the highseas fisheries around Hawaii and westward through the Trust Territory of the Pacific Islands in attempts to uncover new marine resources for the American dinner table. Valuable information on the distribution of tuna in these waters is being obtained, along with facts on the abundance of this highly important food fish. Similar studies are being made by the Service in Atlantic and Gulf of Mexico waters, with various species of fish and shellfish under scrutiny. New fishing grounds are being opened up, as a result, and improved methods of catching fish are being developed.

New Gulf of Mexico Fishery

As a result of exploratory fishing by the Service in the Gulf of Mexico, the first commercial catch of tuna in the Gulf was landed at Pascagoula, Miss., last October. The fishing vessel *Santa Antonino* made port during that month with 12½ tons of prime yellowfin tuna taken in the central Gulf region. The fish weighed about 100 pounds each.

In the spring of 1954, Service specialists aboard the exploratory fishing vessel *Oregon* discovered that yellowfin were widely distributed in the Gulf and could be taken at subsurface levels with modified Japanese-type

longline gear. Successful tuna trips were made to various parts of the Gulf and it was found that the central Gulf's northbound current, between 88° and 90° west longitude, afforded the best yellowfin fishing at that time. Making use of this information, the *Santa Antonino* proceeded to this area and reported catches as high as 9 tuna per 100 hooks, a very good showing for this type of fishing.

Another commercial vessel, a converted red snapper schooner operating out of Pensacola, Fla., also began tuna fishing in the Gulf last year as a result of the Service's explorations and findings. Several other vessels are now outfitting for the same purpose. Along with these new activities, tuna canning in the Gulf area is now being considered by business interests. An entirely new industry may well develop from the discovery of tuna stocks in the Gulf.

Conservation of Salmon

To perpetuate the traditional runs of salmon and other food fish in Alaska, the Service is continuing its long-time vigilance over the Territory's aquatic resources. More arduously than ever, conservation measures are being applied as safeguards against undue depletions of the runs.

Alaska's salmon fisheries have been fully utilized for a number of years,

EGG STRIPPING *operations are carried out on many small streams along the Columbia River.*

and the Service has recently found it necessary to impose additional regulatory controls over the commercial take. Through such measures, it is hoped that Alaskan fishermen will reap consistently good hauls in the years ahead.

Considerable effort has been made by the Service in recent years to expand Alaska's latent fisheries, with activities in this direction centering around the yield of king crabs, shrimp, and groundfish. The king-crab and shrimp fisheries have shown gains, as a result, and groundfish are expected to form the basis of a recognized fishery in the not too distant future.

International Development

Increasing emphasis will be placed on the international aspects of fishery resources between now and 1975, according to Service predictions. The need for cooperation among nations has become more apparent with each passing year, and the result has been a rise in the number of international fish-conservation commissions.

Some of the more active commissions at present are the North Pacific Fishery Commission, the Northwest Atlantic Fishery Commission, the International Pacific Salmon Fisheries Commission, the International Pacific Halibut Commission, and the Inter-American Tropical Tuna Commission. The Service is represented on all of these bodies, and Service units contribute research and enforcement work in cases where the convention so stipulates.

A good example of the way in which these commissions further the cause of conservation and greater harvests is the work of the Northwest Atlantic Fishery Commission, established in 1951. Organized to study and help perpetuate the northwest Atlantic's groundfish stocks, this commission is composed of representatives from the United States, Canada, Great Britain, Denmark, Norway, Iceland, France, Italy, Portugal, and Spain. The waters off New England, Nova Scotia, Newfoundland, Labrador, and Greenland — where fisher-

EXPLORATORY *fishing vessel* OREGON, *used in Fish and Wildlife Service operations in the Gulf of Mexico. Development of Gulf tuna and shrimp fisheries is the* OREGON'S *chief current task.*

men from these ten nations operate—have been under surveillance, and conservation measures have been promulgated. A regulation for conserving undersized haddock, adopted by the commission in 1952, is expected to swell the sustained haddock yield in this area by about 30 percent. The small haddock now being spared for growth and future harvesting by New England trawler fishermen alone have been valued at $1,000,000 per year.

Other commissions have been similarly effective. As international teamwork grows, America's nutritional needs from the sea—and those of our neighbors around the globe—will be cared for. As nations pull together in this common effort, the world's marine waters will do their part.

Books *By Foundation Members*

Elements of Ecology, by George L. Clarke. John Wiley & Sons. Dr. Clarke, Associate Professor of Zoology at Harvard, is also Marine Biologist on the staff of the Woods Hole Oceanographic Institution and has recently been working on the penetration of light in sea water at the Marine Laboratory, University of Miami. His new book tells of the fundamental scientific ideas underlying the relationship of life in the sea, on land and in freshwater. While it is primarily a scientific textbook, nevertheless the layman who has a serious interest in conservation will find this book readable and full of information. It is well illustrated.

Golfstrommens Saga, by Chapin & Smith. "The Ocean River," dealing with the Atlantic system of currents, of which the Gulf Stream is part, enjoyed a wide circulation when published by Scribner & Son three years ago. It is now also available in Germany and Denmark under the titles "Der Golfstrom" and "Golfstrommens Saga." The book has especial interest because of its attempt to show the influence of the Gulf Stream upon the North Sea countries and the New World as well as the development of scientific knowledge of the Atlantic Ocean, its currents, and the life within it.

The Sea of Feast and Famine

TODAY, THE UNPRECEDENTED rate of increase of the human race has caused the more thoughtful to look with a critical eye to future sources of food. As a result, the relatively unexploited food resources of the ocean have been brought into sharp focus. With 75,000 new mouths to feed every day the practical fishery scientist is concerned with the development of fishery economics and engineering and with exploration for new fisheries to the end of increasing food-fish production. Other marine scientists, interested in more fundamental problems, are seeking to explore the great unsolved problems of the sea as a physical and chemical system, the habits and nature of the amazingly varied kinds of life in the sea and the complex relations which exist between this life and the sea itself, and profoundly affect the rate of production of life in the sea.

The Fertile Sea

One area of the ocean has been of particular interest to oceanographers in recent years. It may well be called the Sea of Feast and Famine. The Pacific coast of South America, stretching from Chile by way of Peru north to Ecuador and the equator is marked by a huge abundance of marine life. In these waters great schools of bait fish are eaten not only by the larger market fish but also by birds. The amount of life is so great that often the water is churned up for miles around by the fish and the air is thick with clouds of birds extending in all directions. The birds, supported by the rich harvest of fish, are in fact so numerous that the Peruvians are able each year to harvest thousands of tons of their excrement or guano, which is a rich and valuable fertilizer.

Large fish feed upon small fish and small fish feed upon the microscopic life of the sea, the plankton. The plankton in turn is eventually dependent upon the fertilizer materials of the sea, just as land animal life depends upon the vegetable food crops of the soil and these in turn depend upon soil fertility.

The Seven Year Plague

The oceanographer is immediately curious to know what there is about the ocean off the Pacific South American coast which makes it so fertile, sufficiently so to support the giant broadbill swordfish and fighting black marlin, weighing as much as 2,000 pounds each.

The teeming life of this strip of the salt water seems to be associated with the Peru Current, a large movement of cold water which flows from the southern part of Chile along the coast as far as Cabo Blanco in northern Peru, before turning out to sea as the westward flowing south equatorial current. Of even greater interest than the Peru Current to most people living along these shores is El Niño, which is the name given to a strange happening that occurs at irregular intervals averaging about once in seven years and associated with disastrous

MEMBERS *of the University of Miami-Lou Marron Expedition to South America while in Ecuador. No question of taking the bus to work. Instead it was the bongo, native dugout canoe paddled through the heavy surf.*

results. In the early months of an El Niño year the coastal Peru Current disappears and in place of its north-flowing cold waters the shore becomes bathed by warmer less salty waters drifting southwards. The land, though normally very arid, often receives during the time of El Niño a great deluge of rain. The coastal waters become discolored and those fish which do not leave the waters are killed in catastrophic quantities. Not only do dead fishes drift onto the shore in great windrows but the guano birds, faced with loss of their food, leave the rookeries. The young birds are deserted and are the first to die, followed by large numbers of the adults.

This strange contrast of feast and famine attracted the attention of explorers, oceanographers and meteorologists as far back as 1543, when Zarate was sent to Peru by the King of Spain as Treasurer General. He early suggested the part played by offshore winds in driving the Peru Current on its way and it is recorded that the conquistadores took advantage of the contrast between its cold waters in the tropical climate to cool their drinks by hanging their flasks overboard. Since Humboldt's observations in 1802 three French expeditions studied these waters between 1823 and 1840, but it is only in the past twenty or thirty years that modern methods of observation and modern principles of oceanography have been applied to the fertile cold part of the Peru Current and the catastrophic warm reverse flow of El Niño.

Between 1543 and 1930 a total of about 90 accounts were published, varying greatly in detail. Nevertheless the first really satisfactory explanation of the Peru Current and El Niño was that of Gerhard Schott, who studied observations made mainly on the German vessels *Emden* and *Nitrocris* and published in 1931. At about the same time H. V. Sverdrup published accounts of the first modern underwater measurements made offshore here. They were carried out aboard the research vessel *Carnegie* while Schweigger, working for the guano company, gave similar information for the inshore waters.

The Explanation

The time was now ripe for the most detailed study so far made. Herman Gunther, relying on the results of an exploration made by the British research vessel *William Scoresby* was able to confirm and enlarge the ideas first advanced by his predecessors in a major publication of the Discovery Committee.

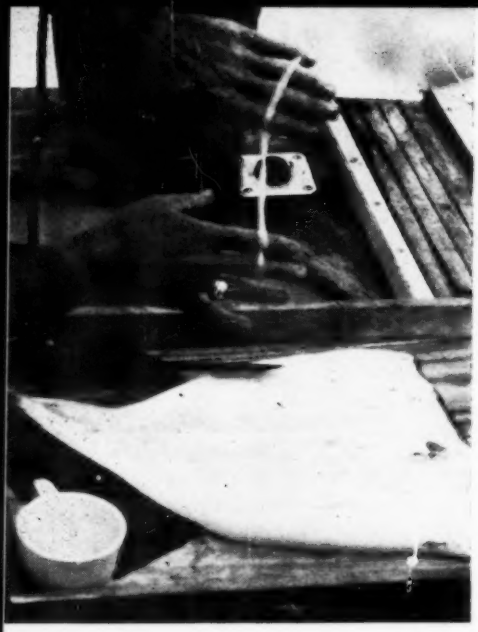
In a general way it was shown that the Peru current is part of a great anticlockwise circulation that travels around the South Pacific. This circulation, moving eastward in the most southerly latitudes, turns north along the coast of Chile and Peru, driven by the prevailing southerly winds. Offshore the winds are more typically southeast trades. The net result is that the waters further from the coast and to the north of Peru drift west again to complete the circulation. Various ideas had been put forward to account for the coldness and rich fertility of the Peru Current when it runs along the coast. Gunther and later workers have confirmed the belief of Schott that, in general, this is due to a series of upwellings whereby deeper colder water rises to the surface at various places along the shore. The deeper water is colder since cold water is usually heavier and sinks below the surface. It is also generally true that deeper water is richer in fertilizer material. This is due to the fact that, as sealife, particularly the plankton, lives, grows and finally dies at the surface it causes a continual rain of microscopic decomposing bodies to sink towards the bottom. There, just as compost releases fertilizer to our gardens, so the plankton rain enriches the deeper waters.

As Gunther pointed out, the probable reason for the rising of cold rich water along the coast of Chile and Peru is that there is a general tendency for the water to move offshore, under the influence of the prevailing winds and so deeper water rises up to replace it. There are four principal areas in which this takes place, at Caldera, between Antofagasta and Arica, at San Juan and at the Lobos Islands south of Cabo Blanco. In each of these areas the uprising of water is associated with an anticlockwise swirl or eddy of water.

El Nino

Having explained the reasons for the normal richness of these waters there still remained the problem of finding a satisfactory reason for the lean and disastrous years of El Niño. Suggestions made by Schott were further extended by Gunther and it is now fairly well agreed that the immediate cause is a southward flowing current of warm water, extending

MAP OF THE PACIFIC COAST *of South America. The current normally flowing close to the shore as far south as Cabo Blanco is greatly increased during an El Niño year and may extend much further southward with disastrous results. For the purposes of this article the map is diagrammatic and simplified. It does not show, for instance, the offshore part of the Peru Current, and various other features are exaggerated.*



THE GIANT NERVE *of a sea squid dissected out during the Miami expedition to South America and shipped immediately to M.I.T. for study.*

from equatorial regions as a tongue or wedge between the Peru Current and the shore. This is a result of the fact that, in the southern summer, which is our winter, the wind systems of the world have a tendency to shift southwards. Because of this the water current systems, largely driven by the winds, are also displaced south. It has been shown that some warm equatorial water runs southwards to a limited extent every summer, because of this effect. In an El Niño year, however, the southward displacement of the wind system is particularly great and the result is an abnormally strong warm southward flow of equatorial water along the coast, which displaces the colder portion of the Peru Current and pushes it well offshore. The consequent sudden changes in temperature of the near shore water bring about the death of the marine life. Added to this is the effect of the abnormal rains, also due to the displaced wind system. These further dilute the El Niño waters and the decrease in saltness is likewise harmful to marine life.

Following the work of Gunther and the R. R. S. *William Scoresby* a few later attempts have been made to work out the details of these complex current systems, notably by the Scripps Institute of Oceanography, whose vessel *Horizon* in 1952 obtained observations which suggest that there are not only more or less permanent eddies associated with upwelling of deeper waters, but that temporary eddies, moving with the current, may also be developed.

Sportsmen and Science

The problems are by no means all solved. We still need to know far more about the fluctuations in upwelling and their causes and the exact relationship between the wind system and the development of El Niño. Only more exact knowledge will make it possible to understand and one day perhaps to predict the migrations and the varying abundance of the fishlife. This has its obvious value to the economy of the countries concerned. It also strikes home to those hardy individuals who get their sport in catching on rod and line swordfish and black marlin weighing the better part of a ton. They too have noted the great fluctuations in catch from year to year at Cabo Blanco and Iquique. The American Museum of Natural History, financed by Michael Lerner, made some of the first studies

of the Chile and Peru ocean gamefish in 1940.

The first group of anglers to outfit a full scale scientific expedition to study these fishes and the general problem of food production in the Peru current was headed by Wendell Anderson. With John Olin and a number of other well known big game fishermen, Anderson made it possible for Yale University to set out in 1953 for Peru in order to spend three months studying these giant fishes and in order to bring back molds of Pacific fishes for exhibition purposes. Altogether over 3,000 specimens of small fishes were collected and also a number of marlin. The expedition was carried out by several vessels equipped for the work.

By chance the Yale expedition arrived on the tail end of a mild El Niño and were thus able to obtain observations on the water movements which José Barandiarán of the Peruvian Hydrographic Office used to confirm many of the theories previously advanced. Unfortunately El Niño was probably the cause of reduced fertility that year and the plankton catch was relatively poor.

In 1954 another big game fisherman, Louis Marron, with his wife Eugenie, accompanied by John and Georgia Manning, financed a further expedition by the Marine Laboratory of the University of Miami for the purpose of studying the entire coast from Chile to Peru. Included in the six month long program were not only studies of the giant game fish but also of the commercial fisheries and general productivity of the whole length of the Peru Current.

The work was carried out entirely aboard the 46-foot vessel *Explorer*. Although especially built for the work, her small size made it necessary for the most part to work from shore bases with offshore trips of one to several days at a time, for collecting fishes and studying plankton and the ocean currents. Nevertheless results were good. Both marlin and swordfish were studied in detail and, in addition, subsurface seawater temperature measurements in the neighborhood of Ecuador gave good evidence that, in this region, part of the Peru Current, instead of shifting to the west, actually continues north, beneath the surface and beneath the southward drift of equatorial waters. The Miami expedition was able to examine 79 specimens of marlin and swordfish, a most impressive total.

Such expeditions as these and the longline expedition conducted for exploratory fishing purposes by Scripps Institute aboard the vessel *N. B. Scofield* in 1953, between the mainland and the Galapagos islands, will eventually yield the detailed understanding that is needed. Space does not allow a detailed description of these expeditions in the present article. It is hoped, however, that future issues of this bulletin may cover some of the fascinating day to day experiences that go to make up such ventures.

Radar in Ocean Science

By WM. L. FRESEMAN

DURING WORLD WAR II everyone heard of a new and strange device called "Radar". To it were often ascribed magical properties. It could detect enemy aircraft at great distances, ships enveloped in fog or darkness, and even high speed projectiles in flight toward a target. Radar could afford information as to the precise distance, bearing, and direction of movement of enemy targets, thus permitting our own forces to intercept enemy planes and ships, or to lay our guns in the proper direction to destroy his positions on land or sea which might be invisible to the eye. Today its uses have expanded in many directions that are not generally known.

A New Safety Device

After the war our scientists gradually adapted radar to peacetime uses, but that task is far from complete. Many of us are now aware as we roll along a main highway in our cars that our speed may be checked at any moment by mobile radar equipment operated by the local police department. All commercial aircraft may eventually be required to install a radar set to aid them in their navigation, particularly in surmounting mountain ranges not visible otherwise in bad weather or darkness; railroad trains can be equipped with modern radar to avoid collisions; aircraft can be landed at airports in zero visibility by a ground control landing system utilizing radar as its primary component.

To those who follow the sea for business or pleasure, radar offers the greatest aid to safety in modern times. In reduced visibility it can detect the approach of other craft, the proximity of icebergs or other above-water dangers, and assist the navigator to avoid these hazards. With experience in its use, radar can offer vastly increased safety when piloting on soundings, or when making a landfall. It can even be utilized to pick up the buoys on each side of a channel and thus assure relatively safe navigation in a dense fog through tortuous stretches of this restricted type of water.

The Principle of Radar

Actually the principle underlying the marvel of radar was discovered as long ago as 1922, but its effective utilization was not accomplished until just prior to the outbreak of World War II. The fact that an argument did exist as to the country responsible for the discovery—the United States or Great Britain—is of no importance today. The discovery was apparently made on both sides of the Atlantic at approximately the same time although Britain led the way in the early practical applications, which were devoted entirely to warfare.

The underlying principle is quite simple and can be grasped by any non-technical mind, although the electronic techniques are quite complicated. Everyone understands how the voice or other sounds can be made to reflect from the faces of cliffs, particularly in a narrow valley, or from the walls in a long hallway or building.

resulting in the familiar phenomenon of the echo. In the same way the ordinary electromagnetic waves utilized to bring radio and television into the home are also reflected from objects in their path. However, if the beamed signal were transmitted continuously, the detection of the reflected energy would be impossible, since the outgoing signal would interfere with and obliterate the reflected signal.

Let us see how radar solves this problem.

The properties of electromagnetic waves and light are very similar, and they both travel at a speed of 161,800 nautical miles per second. At this rate the radar beam requires 618/100,000,000 of a second (.00000618 second) to travel one nautical mile. Electronic engineers call one millionth of a second a microsecond, so the period to travel one nautical mile becomes 6.18 microseconds. This time interval may appear microscopically small to the layman, but electronic equipment is being built which can differentiate periods of less than one microsecond.

The signals sent out by radar consist of a series of short pulses separated by longer intervals. Thus the radar may be considered as an electromagnetic machine gun, firing very short bursts of radio waves with a relatively long silent period between bursts or pulses. The pulse length may vary from less than one microsecond to six or seven microseconds.

The purpose of transmitting the energy in short bursts, with a relatively long interval between them, is to permit the energy of one of these bursts or pulses to travel to the target and then to return to the radar before the next pulse is emitted from the antenna. Thus the reflected signal can

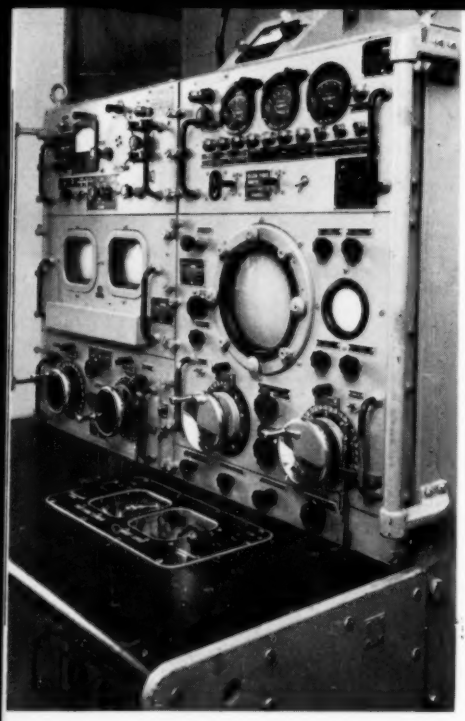
ADMIRAL WILLIAM L. FRESEMAN *adjusts the antenna of the hurricane hunting radar at the University of Miami.*

be detected by suitable electronic apparatus without the interference which would result if a continuous signal were transmitted by the antenna.

Since radio waves travel one nautical mile in about 6.18 microseconds, for a target located 100 nautical miles from the radar it will require

$$100 \times 6.18 \times 2 = 1236 \text{ microseconds}$$

to see the signal on the radar, for the signal must travel 200 nautical miles (100 miles out for emitted signal and the same distance back for the reflect-



CONTROLS *of the high powered radar equipment used in studying the development of hurricanes at Miami.*

ed signal). Therefore, as long as the interval between pulses is at least 1236 microseconds, objects out to 100 miles can be detected by the radar. This means that approximately 800 pulses per second, with each pulse about 2 microseconds in length would accomplish this. If a greater range of detection is required the time interval between successive pulses must be made correspondingly longer.

The maximum effective range of any radar depends also on the amount of power emitted from the antenna, just as a radio broadcasting station increases its area of coverage by increasing its radiated power. Intimately connected with this feature is also the sensitivity of the radar receiver, or its ability to pick up and amplify radar echoes of infinitesimal strength. The electronic circuits and devices incorporated into a complete radar set to measure accurately time intervals of one millionth of a second are relatively complicated, although the basic principle of radar itself is surprisingly simple.

Radar and the Hurricane

In the early days of radar development it was found that radar echoes could be obtained from rain and snow, particularly on radars utilizing the smaller wavelengths; i.e., 10 cm or less. Even clouds at great distances can be detected with very small wavelengths; i.e., 3 cm or less. This feature of radar gave birth to the newest of sciences—radar meteorology—and soon radar should become an essential tool of the forecasting meteorologist. The ability of radar to detect and *track* meteorological phenomena such as cold fronts, thunderstorms, hurricanes, waterspouts, tropical rain squalls and easterly waves, should be of intense interest to the seafaring man—professional or amateur. By observing and plotting from the radarscope the course and speed of these hazards, or undesirable weather features, the mariner can frequently avoid them by appropriate changes in his own course and speed, or at least make adequate preparations in his craft to cope with the type of weather to be encountered. The "mackerel sky" and "moon halo" sailors can now have a device to support or dispute their time-hallowed weather prognostications.

But radar is also being used by the research meteorologist to delve into the secrets of hurricanes, tornadoes, cold fronts and other phenomena, and it promises to reveal many facts and features of all these phenomena which are obtainable in no other manner because of the intensity of the elements within them. From this basic research will eventually be derived methods of determining the centers of hurricanes from a distance too great for the radar to "see" the entire storm; a process to enable the meteorologist or seaman to predict accurately the future paths of hurricanes; measurement of the intensity of rainfall at any particular instant from observation of the radarscope; degree of turbulence in any disturbance; velocity and direction of the wind at any desired location within radar range; height of precipitation levels in the atmosphere; detection of incipient storm or hurricane areas; and specific rules or guides for the interpretation and use of radarscope information for weather forecasting by the mariner or practical meteorologist.

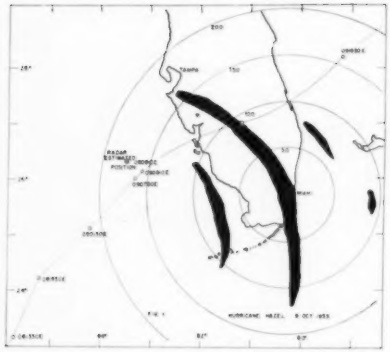
Radar Research Laboratory—University of Miami

Photographs accompanying this article show sections of the Radar Research Laboratory which is being used by the Marine Laboratory of the University of Miami for the advancement of radar development and radar meteorology, not only for the meteorologist and his work in protecting the world against the elements, but for the safety of the seaman who does not possess technical meteorological qualifications or instruments, but who may have available a small amount of "rule of thumb" meteorology plus a radar.

For the purpose of this research work, the Radar Research Laboratory with its electronic engineering staff, is completely integrated with the Marine Laboratory of the University with its highly qualified meteorological staff. The equipment pictured in these pages is exceptionally high powered and bulky, but particularly suitable for research activities. It occupies the space of two sizeable rooms, but the ordinary radar equipment now used on ships for short-range navigational purposes may be contained in a box as small as three or four cubic feet. With a few modifications many of these could be used also for meteorological purposes.

Research work since the establishment of the Radar Research Laboratory in May, 1953, has included studies and tracking of hurricanes,

THE RADAR INSTALLATION *at Miami has a large size projection table for mapping the progress of weather fronts and hurricanes, which can be observed hundreds of miles away.*



SQUALL LINES *or precipitation bands sketched on radarscope during tracking of hurricane* HAZEL, *October 9, 1953.*

thunderstorms, and easterly waves, and methods of detecting incipient hurricane areas. The illustration shows a radarscope sketch of radiating squall lines from a hurricane. These spiral lines are being investigated for the possibility of determining from them the location of the hurricane center and its movement. Another figure shows an incipient hurricane area sketched from the radarscope. The area was discovered not only from the appearance of the suspicious region, but confirmed by tracking of the individual precipitation cells. 35 mm films taken of the radarscope during studies of a thunderstorm area and an easterly wave are also shown.

The Marine Laboratory and Radar Research Laboratory of the University of Miami hope to continue this pertinent research and to develop methods for practical utilization of radar for both the meteorologist and mariner. There exist only about a half dozen radar meteorological laboratories in the United States, and the University of Miami has the only one ideally situated for the study of both tropical and sub-tropical weather phenomena. The degree and speed with which results of practical value can be obtained depend only on the amount of support that will be available.

The Future

Despite gigantic strides during the past 15 years, the radar art is still in its infancy. Even so, radar is today of inestimable value to those who sail the seas. Once one of us uses radar to help solve his navigational problems, he dislikes to sail again without it. The price of radar equipment, formerly considered too expensive by steamship companies, has dropped steadily. Now a short-range navigational set is available to the yachtsman at prices ranging from $3,000 to $10,000. Eventually these prices should drop further, and there is no reason why future sets cannot utilize a wavelength suitable for meteorological observations as well as navigational use.

In the years ahead other uses for radar will be developed. A recent report from Europe claims that submarine radar equipment has been used successfully to detect schools of fish running in a channel. It is not inconceivable that radar might someday be used to detect the approach of objects such as asteroids from outer space. A radar beam has already been bounced off the moon and its computed distance from the earth verified by the time interval between the outgoing pulse and the returned echo. The Marine Laboratory at the University of Miami is now developing a procedure to obtain extremely ac-

curate determinations of current drift in the Gulf Stream utilizing radar.

Though speculation of the radar future is intriguing, right now the Oceanographic Foundation is interested in realizing a wider use of radar for navigational and meteorological use at sea, the development of smaller, better, and cheaper radar equipment for these purposes, and the early formulation of practical radar guides for the seaman to permit him to realize the utmost from his radar for meteorological purposes. The furtherance of the safety of the seafarer and the enhancement of his profit or pleasure by the further development of radar and methods in its use, is deemed a project worthy of intense prosecution.

Last night I saw St. Elmo's stars,
With their glittering lanterns all at play
On the tops of the masts and the tips of the spars,
And I knew we should have foul weather today.

Longfellow

In Support of Oceanographic Research

The following donations have recently been made to the Foundation:

Shell Development Company. $1,000 to establish a fund for research on Florida marine sediments.

Mr. Roger S. Firestone. $3,000 to establish a fund for research on the tarpon.

Members of the Foundation have also made the following contributions to oceanographic science:

Mr. George Collier. Property and stock certificates to establish a fund for research buildings at the Marine Laboratory, University of Miami.

Brigadier General Robert Wood Johnson. The motor yacht *Gerda* for conversion to an oceanographic research vessel for the Marine Laboratory, University of Miami. This fine seagoing vessel will be used principally for offshore research on the Florida Current and other Navy sponsored research.

Mr. Erik Wijk. A contribution for the general purposes of the Foundation.

The Motor Yacht GERDA

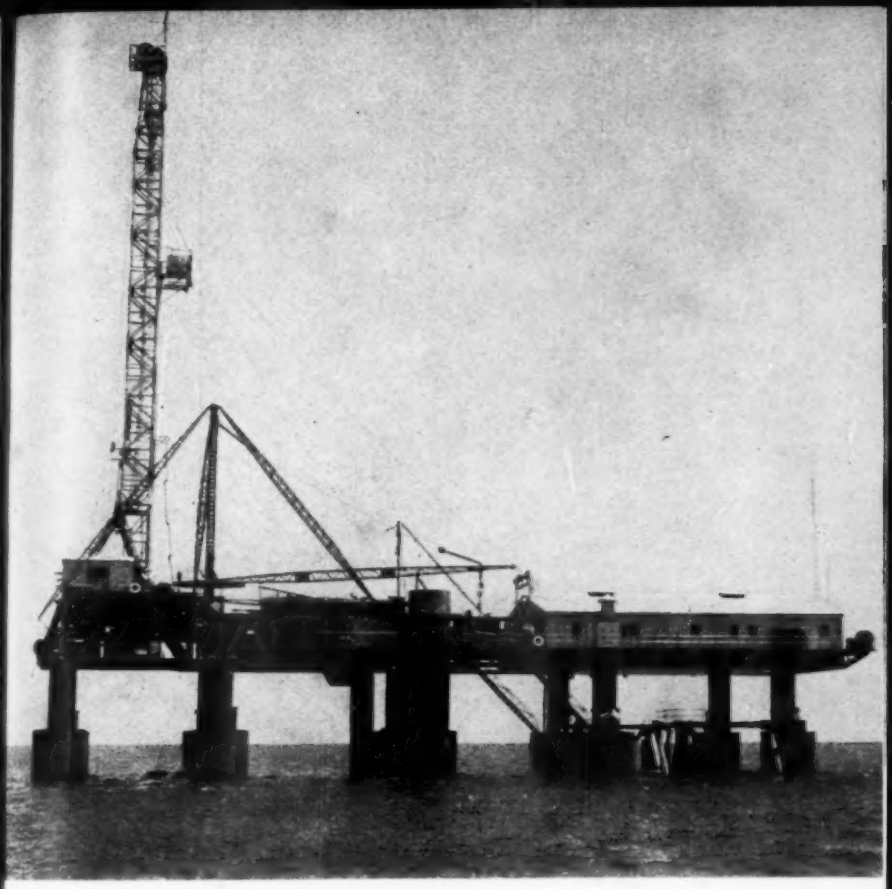
Marine Microbes

By SELWYN J. BEIN

MANY PEOPLE are of the opinion that all bacteria are harmful. The word "germ" immediately brings to mind disease and discomfort. Fortunately, the actual truth of the matter falls much closer to the other end of the scale. With the exception of a relatively few kinds, bacteria fall into the category of being harmless and many are actually helpful or necessary to the comfort and well being of humanity. This has been known for some time about fresh water and land bacteria. The use of these microscopic organisms in dairy processes, farming, and various industrial fermentations has been firmly established. Many people make use of *Lactobacillus bulgaris* for the production of yogurt in the home. Farmers know how important it is to have nitrogen fixing bacteria in the soil for the production of a good crop. These are established facts.

Unfortunately the bacterial "do-gooders" of the ocean have been overlooked. This is partly due to the concentration of research on the land forms and partially due to the lack of funds for investigators in this field; nevertheless it is believed by some of the world's leading economists that man must eventually turn to the sea for at least partial help in maintaining an adequate food supply for the coming generations. Investigations have been concentrated to date on the fish, algae, and plankton, the microscopic plants and animals of the sea. Although bacteria constitute a portion of the plankton, lack of attention to them is understandable because their actual bulk is relatively small when compared to the other living things taken in a typical plankton haul. It is also true that the specially designed fine nets used for collecting plankton are not designed to trap creatures as small as bacterial cells so that they then pass through unnoticed. Even when special bacterial samples are taken, little or no effort is usually made to identify them because, unlike most other organisms, they cannot be identified by microscopic examination alone and must be put through a series of rather complex laboratory tests to determine their identity through their reaction to food and chemical substances. These tests in themselves are often good clues to the possible value of the bacteria under observation. It is not enough merely to find and isolate useful microbes. Other work must follow in order to maintain them in the laboratory by a simple and inexpensive culture method. Investigators are not only interested in unusual laboratory phenomena but also in culture methods available to technicians so that they may grow bacteria by mass production for general and industrial distribution. These are the problems to be overcome.

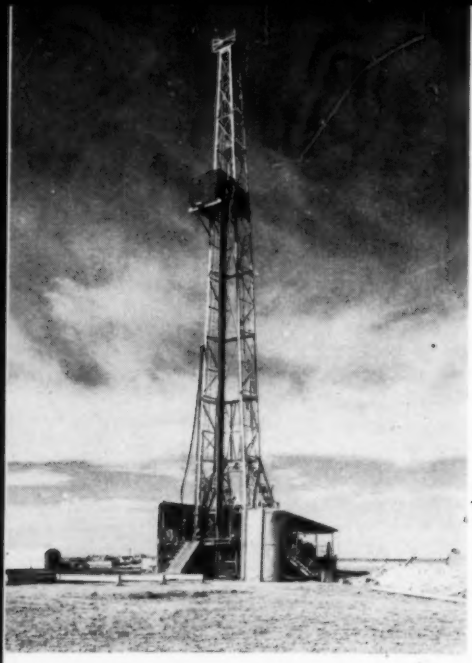
The role of these invisible creatures in the production of petroleum is a fabulous tale. The story of our huge oil industry began in the ancient shallow seas. These seas on several occassions in the last two billion years have covered large parts of our continent, where Kansas, Texas, Pennsylvania, and other midcentral oil fields are today. Millions of tons of planktonic organisms constantly rained down upon the ancient sea floor just as they do today. There they were attacked by the bacterial population inhabiting



MODERN OIL EXPLORATION *is tapping the sediments laid down in ancient seas. In some cases these rocks are still beneath water and the oceanographer today helps in the design of offshore rigs by his studies of wave action.*

the slime and ooze of the bottom. By exertion of their magic properties drastic chemical changes occurred and the first steps were made in the production of an oil field. These microbes continued their chemical activity despite the lack of free oxygen. Millions of years later the old sea floors have grown to be thousands of feet thick from the slowly accumulating sediments and are now part of the rock beneath our feet. When these rock strata are probed by the relentless oil seeking drill the forthcoming gusher may yet contain the living decendants of these ancient bacterial cells. Fantastic as this may appear it is backed by scientific fact.

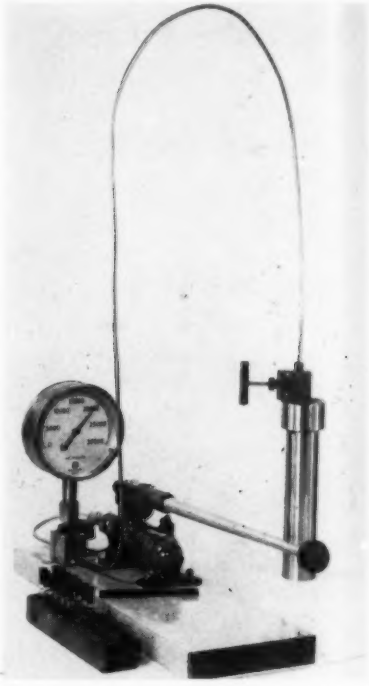
The American Petroleum Institute in 1950 sponsored a project under the supervision of Dr. Claude E. ZoBell of the Scripps Oceanographic Institute. Dr. ZoBell, who is recognized as one of the world's leading marine bacteriologists, concluded that "Bacteria



THE MODERN DRILLING RIG *produces oil from dryland rocks thousands of feet deep—but nevertheless part of an ancient sea floor.*

and allied micro-organisms are responsible for the first steps in the formation of petroleum from organic matter deposited in marine sediments." He further states that "This conclusion is inescapable because the organic remains of all plants and animals are susceptible to attack by bacteria and their enzymes." Laboratory experiments carried on during this investigation have produced residues petroleum-like in character and the fact that bacteria are capable of releasing oil from oil bearing materials. It is not beyond possibility that oil may be produced under human controlled conditions to replace our ever diminishing stock of this vital commodity.

A familiar product from the sea is agar. This has been used for some time by industry and medicine. It is often prescribed by doctors for adding bulk and roughage to human diets. It is used in the manufacture of ice cream and jellies, in paper sizing, and leather treatment. Unfortunately, as a source of nutrition it is valueless despite the fact that it is a sugar. The very complexity of this sugar makes it unsuitable for human digestion.



EQUIPMENT USED *in studies conducted at the University of California's Scripps Institution of Oceanography on the effects of pressure on marine micro-organisms. Bacteria have been collected from some of the deepest parts of the ocean by Dr. Claude E. ZoBell, Professor of Marine Microbiology. Using this equipment, he can reproduce the pressure of their original habitat.*

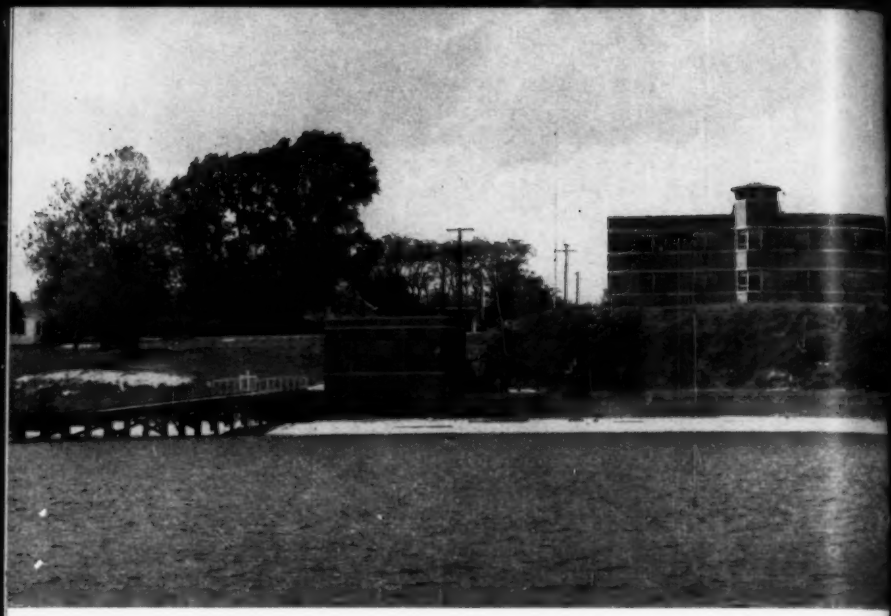
This is where bacteria may help. Partial decomposition of the agar sugar by marine bacteria may reduce it to a simpler substance which may be highly nutritious. The fact that this reduction is completely odorless may make it highly desirable for commercial processes.

Bacteria have in their repertoire of useful tricks the ability to manufacture some of the necessary vitamins. Some of the marine bacteria belong to this group although there has been little exploitation in this field.

Commercial fishing today is in the hunting stage and may be likened to the early pioneers hunting off the land and eating the fruits and vegetables that grow wild. Extracting food from the sea may eventually be developed to the counterpart of farming the land. When this stage is reached it would be a valuable tool to know which bacteria provides the vitamins necessary to maintain these "domestic" plants and animals. It is certainly important to know just what part they play in the normal life of the sea.

A valuable contribution would also be made of the beforehand knowledge of what causes disease in marine fish and plants. The existing antibiotics are sometimes found to be ineffective on marine bacteria and new ones may be developed from ocean forms. It is also plausible that new antibiotics may be developed from these oceanic inhabitants to combat the existing human and animal ills.

The versatility of the living chemistry of bacteria is practically boundless. They are capable of surviving under conditions that appear impossible. As a group they can survive with or without atmospheric oxygen. Some specialized forms are capable of utilizing sulphur, they can produce and destroy cellulose, survive below freezing and above boiling temperatures, live in the absence of water, and be revived after years of almost total dormancy. Because of this versatility and the fact that many more of these fantastic creatures remain to be discovered, this field of marine research offers both basic science and industry an almost infinite number of possibilities.



VIRGINIA'S *Fisheries Laboratory overlooks the historic York River.*

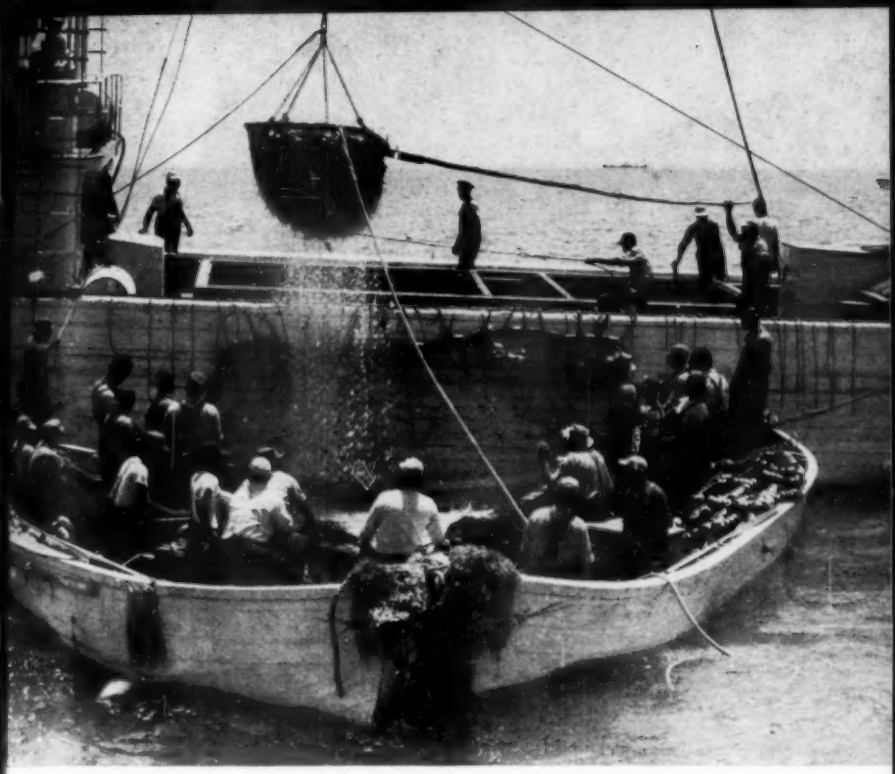
The World's Best Fishin' Hole

LOOKING FOR A QUIET DAY of fishing? Prefer to match wits with a fighting bluefish or striped bass? Or do your tastes run to plenty of bites, and a boatload of fish to bring home? Whatever your pleasure, residents of tidewater Virginia will tell you that the Chesapeake is the world's best fishin' hole.

Many people will dispute this statement. Since colonial days the Chesapeake Bay has been famous for its seafoods, and more recently has become an important sport fishing area. How rich and how productive is this great enclosed arm of the ocean?

Are Some Chesapeake Seafoods Disappearing?

Perhaps the most striking event of recent years has been the casastrophic decline in commercial landings of croaker, once by far the leading food fish in the Virginia catch. Since 1945, the official records of the U.S. Fish and Wildlife Service tell us, the commercial catch of this important fish has fallen from 55 million to less than 5 million pounds. Another leading food fish, the gray trout or weakfish, has shown a similar decline. The operators of pound nets, many of whom depended mainly on these two species for profitable operation, have suffered accordingly, and the nets in operation today represent only a fraction of the thousands that once extended, end to end, and row upon row, out from Virginia's 1500-mile shoreline of the Bay.



MENHADEN *by the thousands come aboard as the brailer scoops the catch from the purse seine.*

The Oyster is King in Virginia

The Chesapeake's most valuable seafood is the famous Virginia oyster, which accounts for more than one-third of the entire income of the State's fishermen. Standing second is the delectable blue crab, with landings worth millions of dollars annually. Ranking first of all marine products in weight of landings, but only third in value, is the menhaden, which, though not eaten by man, is important in the diet of many commercial and sport fishes.

The Chesapeake oyster industry is certainly the world's greatest, for the Bay contributes two-fifths of the U.S. production, and about one-fourth of the crop of the entire world. Evidence of this thriving industry is everywhere, for if one object can be said to be characteristic of tidewater, it is the ubiquitous oyster shell. But fundamental changes are taking place in the oyster industry. The harvest of adult oysters from the natural grounds has been declining for some years, but a steady increase in the crop from otherwise barren ground leased to planters has slowed the downward trend.

Other Seafoods Abundant

The picture is not entirely bleak, for the blue crab catch, though nota-

bly erratic, has shown no downward trend, and menhaden may well be more abundant in the Bay now than ever before in history. Other species are filling to some extent the void left by the vanishing croaker and gray trout, and it is probable that the spot, the river herrings, and several other varieties, could be exploited more extensively without harm. The ebb and flow of abundance of all varieties of life in the Bay is a part of the phenomenon known as "fisherman's luck."

The Virginia Fisheries Laboratory

Our knowledge of this ever-changing system, including the animals and plants, the circulation of the waters, the concentration and distribution of the dissolved and suspended matter, the inflow of fresh water from the many great rivers, and the basic influence of the winds and sun, is fragmentary and imperfect. Until 1940, no major investigation had been made of Virginia's marine resources, or the factors controlling their abundance and movements. Establishment in 1940 of the Virginia Fisheries Laboratory was the first official recognition that the haphazard and often contradictory legislative measures of the past were ineffective, and that management of these important resources should rest on facts, not opinions.

With a new building, completed in 1950, improved facilities, and an accumulating fund of knowledge of the Bay and its major resources, the Laboratory is beginning to prove its worth to the seafood industry and the saltwater sport fisheries. The growing interest of these groups, and of the State Legislature, was demonstrated at the last session of the General Assembly of Virginia, when funds were

TRAYS OF OYSTERS *are examined daily in summer to remove dying oysters.*

appropriated to initiate an investigation of the declining food fisheries and to construct an urgently needed research vessel.

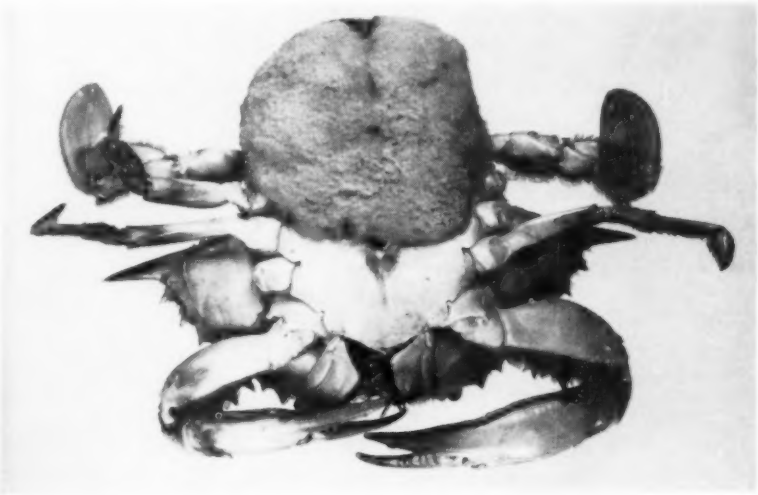
Oyster Disease Under Study

The death rates and growth rates of oysters have received particular attention in recent years. It has been found that most deaths occur in the hot summer months. A fungus disease is mainly responsible for these summer deaths, and much valuable information has been gathered on the rise and fall of infection with the seasons, and the factors, such as temperature and salinity, that seem to control these changes. Out of these studies have come specific recommendations by which oyster planters may harvest more oysters.

Other studies have concerned the oyster drills or screwborers, pests that destroy many millions of oysters each year in the Bay, and completely prevent successful natural seeding in many areas. The object is to find a cheap and easy way to control these enemies.

Blue Crab Spawning Probed

The erratic comings and goings of the blue crab have plagued fishermen in the Chesapeake for generations. When crabbing is poor, the watermen appeal to the lawmakers for help. The laws of Virginia usually have attempted to protect the spawning females, and since 1942 a crab sanctuary has been maintained in the lower part of Chesapeake Bay, in the area where the spawning females congregate. This action seems to have produced no general increase in abundance, and the past twelve years have included some of the best and some of the



FEMALE BLUE CRAB *carries her burden of developing eggs, perhaps a million or more, under her abdomen.*

worst crabbing seasons on record. Unfortunately, as long as no continued decline in catches exists, there is little interest in research. Here, as in many fisheries in the past, an adequate research program may never be possible until dwindling catches provide the necessary impulse.

One of the most intriguing aspects of recent blue crab investigations has been the study of a parasitic worm, that through its complicated habits reveals the spawning history of the crab on which it lives. The immature worm, small and whitish, lives on the gills of the crab. When the female crab spawns, the mass of eggs, called a sponge or cushion, remains attached to the underside of the abdomen. The small, white worms migrate from the gills to the sponge, become sexually mature, and in so doing, increase in size, and change from white to red. After laying their eggs in the sponge, the worms return to the gills. Thus, a female crab bearing only white worms on the gills has yet to spawn for the first time; a female bearing both white and red worms on the gills must have spawned at least once.

Causes of Reduced Shad Catches Sought

The shad and the croaker, two of Virginia's most important food fishes, have been under investigation for several years, and the spawning areas of the shad, in the tidal fresh waters of the major estuaries, are now well known. Present investigations are designed to measure the total numbers of shad that ascend the rivers each year, how many shad escape the fishery to spawn, and the success of each year's spawning in terms of the numbers of adult fish it produces to spawn again. All these will help to answer the question: What effect, if any, does fishing have upon the future supply?

An interesting phase of the shad investigations concerns the movements and feeding of the young fish before they migrate from the rivers to the sea. After hatching, most of the young tend to shift upstream from the spawning area, where they remain for four to six months before the seaward migration begins. On first thought, this habit seems strange, for these waters apparently contain much less food than the salty waters of the Bay. The mystery was solved, however, when the stomach contents of large numbers of young shad were examined. One of the major food items, surprisingly enough, proved to be terrestrial insects. Obviously, these must have been taken at or near the surface, and it is interesting that some, at least, may even have been caught on the wing. That this idea is not entirely fantastic was demonstrated by an alert biologist, who, dangling a line over the side of the boat at dusk, saw small shad leaping to reach the fly he had tied to its end. The stomach contents revealed also that most feeding takes place in early evening, at dusk and shortly after. This is the time, as all who frequent the water know, at which the insects venture out most boldly from the land. Perhaps the fading light so tricks them that they lose their sense of the boundary between air and water. This error is fatal to the insects, but a great boon to the shad and to man.

The Disappearing Croaker

The fascinating story of the croaker in Virginia estuaries has only recently

been told. An understanding of the complicated movements of the young of this important fish has been assisted in no small way by recent work of the Chesapeake Bay Institute, describing the movements of the water in the Bay and its estuaries. Adult croakers apparently spawn in fall and winter in the ocean waters near the Virginia capes. The newly-hatched young, only a fraction of an inch in length, are carried up the Bay and up the major estuaries in the heavy, salty water near the bottom. These deeper water layers, though they move back and forth with the tides, have a net motion up the estuaries. Thus, any objects, living or dead, that cannot or will not stem these currents, will be carried with them.

The baby croakers soon appear well up the rivers, often in great numbers in water that contains no appreciable amounts of salt. Since they are bottom feeders, they stay almost exclusively within the influence of the upstream flow, and during the spring and early summer, as they feed and grow, they may be found in greatest abundance in the upper estuaries, where the salinity is low. As they grow, they move slowly downstream, and by late fall, when the new crop is about to enter the rivers, the yearlings have vacated these nursery grounds. The largest members of this group of juveniles, now six to eight inches long, begin to take the hooks of sport fishermen, and appear in the commercial catch.

The Ever-increasing Sport Fisheries

The important sport fisheries of the Bay are not forgotten. Recreational fishing has multiplied rapidly since the war, and this may be forcing some of the commercial fisheries into relative obscurity. Although the recorded commercial catch of croakers is now only one-tenth of the catch a decade ago, this decline may be more apparent than real. The fish are considerably younger and smaller now than ten years ago, thus the decrease in numbers of fish caught commercially has been much less pronounced than the decrease in weight. Although it is yet too early to say, who can deny that the growing sport fishery, with its unrecorded catch, may account for the remainder? Already, many commercial fishermen have seen the change, and are regaining their lost incomes by taking out parties of sport fishermen.

Research Will Pay Off

These are but a few of the fascinating problems the biologists have pledged themselves to solve. The quest will lead them to follow many trails. The answers should benefit not only Virginia, but may contribute to the welfare of the nation and the world.

Whether or not it can honestly claim the title "The world's best fishin' hole," the Chesapeake is well on the way to getting the scientific attention it deserves.

THE INSIDE COVER PHOTOGRAPH *is simply the tail end of this young bluefin tuna—seen by the X ray machine at the Marine Laboratory of the University of Miami. This machine is a great timesaver in the racial study of fishes.*

X Rays and Marine Biology

By CHARLES E. LANE

VISITORS TO THE LABORATORY often ask why a particular room is devoted to an impressive piece of X-ray equipment. What has it to do with the ocean? The answer is really fairly simple but it carries valuable implications. Important advances in biology, as in many other sciences, are often the result of the improvement of existing instruments or techniques. More dramatic and imaginative is advancement through the adaptation of devices or ideas already used in other sciences but not previously considered for a particular problem. X rays for examining internal organs of the body have been valuable in medical diagnosis for seventy-five years. More recently this method has also been used industrially to reveal hidden defects in structural materials, such as bearings or aircraft frames. X rays have been used by crystallographers to study the inside of the chemical molecule of natural substances. In this role the technique has contributed to the expansion of knowledge of the way in which atoms are arranged within protein molecules, of the internal pattern of carbohydrates like cellulose and glycogen, and even to our conception of the essential structure of certain living viruses. In view of this demonstrated versatility of the X-ray method, it is reasonable to anticipate that it should find wide employment in general biological investigations. In recent years the scientist, always seeking new tools, has been able to do this.

X Rays and Fishes

The most obvious use of the X-ray technique is an extension of its use in medicine, that is to make visible the hidden structures of animals, such as the skeleton. A most interesting application of this type relates to the study of the development of distinct races in fish. It is often found that fish populations may be divided into separate, and genetically distinct, races on the basis of relatively minor differences in the skeleton. Such differences often take the form of variations in the total number of vertebrae making up the back bone of the animals. Before the advent of the X

ray it was necessary that each specimen be laboriously dissected, often under distinctly unfavorable field conditions. After the skeleton had been divested of flesh, it was then cleaned and permitted to dry in the sun. Finally the vertebrae were counted directly. Manifestly this was a time-consuming method and was subject to considerable manipulative error. Nevertheless it was this slow process which enabled Ford and others at the Plymouth laboratory in England to show that the North Sea herring does not, as once thought, travel from the south of England along the coast to Scotland. Instead, by demonstrating that there are separate races at different points of the coast, they were able to explain that the different groups of herring came inshore at different times. Thus what appeared to be a single group moving progressively along the coast turned out to be several groups moving inshore one after another.

Today this work could be done many times more quickly with X rays, which give a picture of each fish's backbone in a matter of seconds and with great accuracy. The X ray of the small bluefin tuna shown on the opposite page, which was made in this laboratory, demonstrates the accuracy and clarity with which a similar determination may be made upon museum specimens or upon living material. Not the least of the advantages of this method lies in its non-destructive nature. One can study fine details of skeletal structure and still have an intact museum specimen.

The recent development of self-contained X-ray equipment utilizing radioactive cobalt as a source of energy makes available a compact, portable unit which is independent of an external power supply. This unit may even be taken directly into the field and used to study the internal structures of large numbers of living fishes during a tagging program, or incidental to other studies of natural populations. Not only such relatively X-ray-opaque structures as bones, teeth and earbones may be demonstrated by this method, but advantage may also be taken of the relative transparency of certain other soft parts of animals to make their study by X ray feasible. Thus it is possible to demonstrate the distribution and structure of the swim bladder in fishes without dissection. Some of the details of the gill structure, of the eye and of the brain and spinal cord are also revealed clearly by X ray.

How Oysters and Shrimps Grow

Related to the study of the skeletons of fishes are other kinds of research on the formation of shells, teeth, and other limestone structures in other animals which may be carried out by the use of X ray. Growth in most shellfish, such as conchs, is associated with formation of shell material, redissolving it, circulating it in the blood and the ultimate redeposition of shell material by the soft fleshy mantle. It is only in this way that the animal can increase in total size and can repair damage to the shell incurred during the life of the animal. All of these changes may be followed accurately in suitable animals by the use of X ray. The internal structure of the shell is also clearly revealed in suitable X ray photographs.

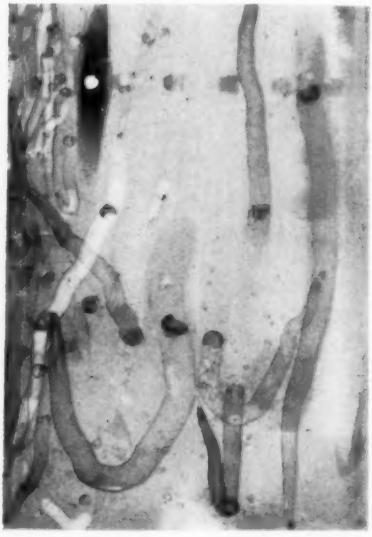
In crustacea, such as the shrimp or the lobster, growth is accomplished by periodically shedding the outer shell or skeleton and replacing it with a

larger one. As might be expected this involves considerable redistribution of the lime salts which are responsible for the bony character of the "shell" in these forms. Beginning of the moult starts with the dissolving of most of the bone-salts from the shell. The salts are then deposited temporarily in reservoirs within the body of the animal. Later they are transferred to the new shell, which is forming beneath the old one. These changes in the distribution of salts may be followed clearly by the use of X ray.

Secrets of the Shipworm

In the Marine Laboratory of the University of Miami the X ray has been used in still a different kind of biological investigation; a study of the life cycle of marine borers which are native to this region. Unprotected wood immersed in sea water, whether it be in the form of a ship, dock pilings, a bulkhead or nondescript flotsam, is subject to attack by the larvae of several wood-boring mollusks. Once these animals have been successful in penetration of the wood, they transform into adults and spend the balance of their lives in the same piece of wood. During their active adult lives they are invisible from the surface of the wood. It was found that they could be visualized with great ease by means of X ray. It was observed, further, that the short exposures of irradiation which were required to secure clear pictures did not interfere with normal growth or development of the borers.

Panels, purposely left unprotected, are immersed in the water of Biscayne Bay and are X-rayed at weekly intervals so long as the panel retains sufficient integrity to permit of its being handled. Most exposure panels are completely destroyed within six months. The X ray is placed over a suitable grid and the location of each borer contained in the wood is noted. The entire life cycle of the individual shipworm is thus lived out in the full glare of X-ray publicity. It is possible to determine the rate at which it bores through wood, the rate at which it grows in girth and length and the total duration of its adult life. None of these data could be gathered without X ray or some other means of visualizing hidden structure.



THE DARKER MARKS *in this X ray photograph are the chisel like shells at the head end of the shipworm — living wood-drills.*

X ray has also made it possible to observe some of the ways in which marine borers go about the business of boring. Examination of many X-ray images has shown the following: the burrows are always separate and never join each other; the burrow is

always limited to a single piece of wood and the animal appears to be incapable of bridging any sizeable gap or crack; there is a definite tendency for the animal always to bore parallel with the grain of the wood; the direction of the burrow may be influenced by the density of the wood through which it passes. There are industrial applications to this, too. The Battelle Memorial Institute is working on a related device, using radioactive materials, for inspecting wooden pilings while still in the water. The saving of time and prevention of damage that this could accomplish is obvious.

This list of actual current applications of the X-ray technique by no means exhausts the possible uses of the method in marine biology. It should be considered, rather, as an indication of the fruitful use to which an exotic tool may be put. Not only in biological oceanography but in chemical, physical and geological studies of the sea we may expect advances to be made as the techniques, tools and instruments of other sciences, the electronics and mechanical devices of the dryland scientist are applied to the problems of the sea.

SHOWN RIGGING *up light tackle at the 1955 International Sailfish Tournament at Palm Beach, Florida, is Dr. Roy B. Dean of Mexico City and Ted Williams of Miami. Doctor Dean, widely known in big game fishing circles, recently has been elected to serve on the Gamefish Research Committee of the International Oceanographic Foundation. Williams is perhaps better known for his baseball playing with the Boston Red Sox, but for many years has specialized in light tackle fishing, especially in fly-rod fishing and spinning.*

START *of the Lipton Cup Race off Miami.* SEA LION *to windward leads* VALIANT.

Estimating the Variables

ONE OF THE PRACTICAL contributions which oceanography is able to make, whereby basic scientific research is applied to useful ends, arises from the need for accurate knowledge of ocean currents. Even today an accurate knowledge of the changes which occur in such fast flowing ocean rivers as the Gulf Stream is valuable to navigation, since as much as 70 miles may be cut from the daily distance made good or added, according to whether the position of the stream is accurately known. To an oil tanker this means fuel and costs of operation and is obviously important.

Apart from the need for this knowledge in navigation and commercial operations, it can also be most useful to yachtsmen in ocean races and in its own way more important, since the minutes and seconds clipped off by taking advantage of countercurrents or of the axis or of little known fluctuations in position may well decide the race. Two years ago the Woods Hole Oceanographic Institution was able to provide considerable help to participants in the Bermuda Race, by estimating the probable course of the Gulf Stream at the time of the race. This year a similar service was given to participants in the Southern ocean races by the International Oceanographic Foundation. The accumulated measurements made by the Marine Laboratory of the University of Miami during several continuous years of studying currents in the Florida Straits and off the West Coast of Flor-

ida were digested in simple form for the information of those racing from Florida to the Bahamas and from St. Petersburg to Havana.

The modern cargo vessel is not too dependent on winds except in the case of severe storms, but an ability to forecast a shift in winds, combined with a knowledge of the fluctuations in ocean currents, is invaluable to the ocean race navigator and so the Marine Laboratory meteorologists added their streamlined rules of prediction for winds as well. Perhaps the new radar meteorology project in Miami, set up to study the ways in which hurricanes, fronts and other wind changes occur will also, as an incidental by-product, help yachtsmen.

Science has many reasons for helping yachtsmen. It is through the efforts of men who give their time and thought and money to ocean racing that a lively interest is kept up in small vessel design and it needs but a brief glance at the records to find how many marine scientists have been recruited from the ranks of those who sail for pleasure. And the part played by yachtsmen in the past war, from the heroic work in private yachts in the English Channel to individual service in the allied Navies, will long be remembered.

Submarine Subversive

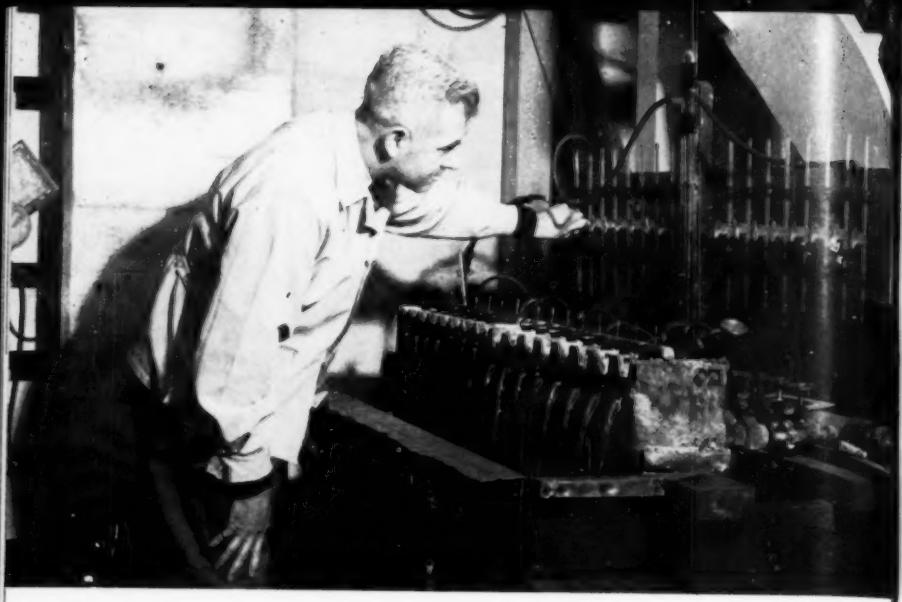
ONE OF THE MOST insidious enemies of steel and other metallic underwater structures, ships' bottoms, water-cooled engines and the like is the condition that causes metals to dissolve in seawater, leaving behind roughened surfaces, pits or holes, or even completely destroying the entire structure. Chemistry is one of our greatest forces for good today. Electro-chemistry has innumerable useful applications. But, let loose in salt water, it is precisely this which corrodes away our steel pilings, condenser tubes and water pipes to the tune of millions of dollars each year.

The scientific investigation of the fundamental problems of corrosion involves an understanding of physics and chemistry, the structure of molecules and atoms and the behavior of electrically charged particles. The more practical application of these principles and the commercial development of corrosion resistant alloys is easier to understand, since it may often be a question simply of trial and error. Nevertheless the purely practical question of which metal will stand up best cannot be divorced from the problem of why some corrode more than others and what are the causes which bring about sudden failure in an apparently satisfactory alloy.

Although the basic electro-chemical principles of corrosion are well enough known there are many situations in which the special and peculiar circumstances completely upset predictions of corrosion resistance based on theory alone. This is where the testing laboratory comes into use and not only does it help to solve the practical problems but its results also provide many new insights into theory.

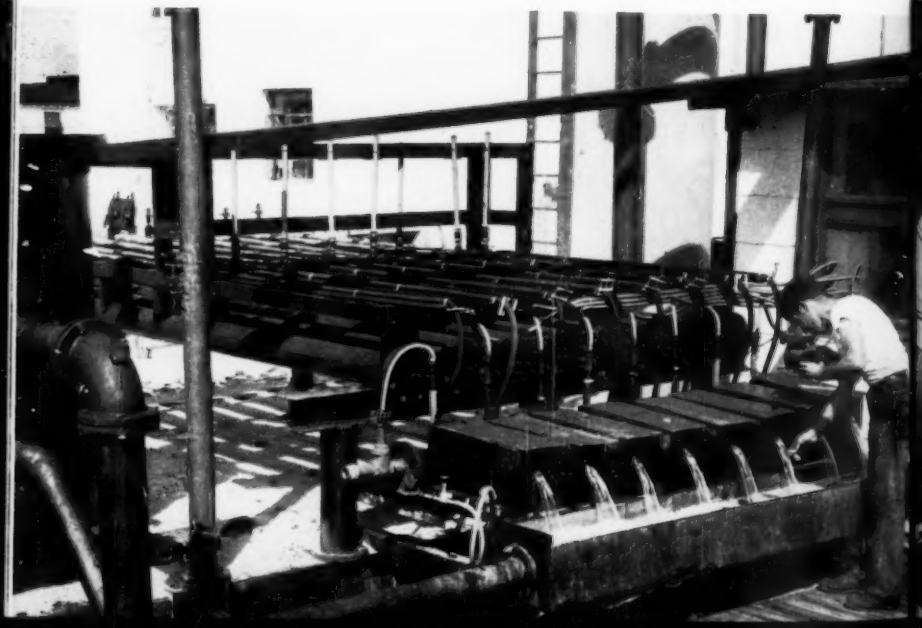
Salt Water Test Tube

One of the world's largest salt water corrosion testing laboratories is to be found not far from the beach at



THIS APPARATUS *was designed to test the effect of impinging water upon metals—just another aspect of the corrosion problem.*

CHLORINE *injected into the saltwater supply to industrial plants may cut down the intrusive growth of barnacles, clams and oysters and so prevent dangerous clogging. This apparatus tells how much chlorine to use.*



Wrightsville, North Carolina, where International Nickel has assembled an elaborate set of testing conditions for seagoing metals which simulate almost any natural corrosion which might be encountered. For example, various types of water piping are set up under conditions of water flow which duplicate the service conditions under which they are used. The entrainment of air in the form of bubbles may also have an effect on corrosion. Sand in the water, the presence of dissimilar metals in the system, barnacles attaching to the surface, all of these may change the corrosion pattern and all may be seen in the tests carried out here. Another useful test consists of placing metal test discs on a rotating spindle which simulates the movement of a ship through water. At the edge of the disc the speed may be equivalent to that of a destroyer, at the middle almost zero. A variation of this test also showed that barnacles will not attach to a surface moving much faster than one knot through the water. This explains why ships which lie idle in harbor are much more likely to foul their bottoms than those in more active service.

A special condition of corrosion may occur when a jet of water impinges on the metal and so, at the test station, a special apparatus is set up for this purpose. Other problems arise when different types of metals or alloys are in contact with each other. For such tests as these the electropotentials and currents between the test strips are measured and the changes due to corrosion products growing on the surface are likewise recorded.

ELECTROPOTENTIALS *developed by metals in contact with each other and with rust and other corrosion products play a large part in the complicated chemistry of corrosion. Here is one of the devices for measuring such effects.*

Many power plants and other large installations which use salt water for condenser cooling or other purposes have been troubled with barnacles, clams, seaweed and even oysters growing in their large pipelines and water intakes and seriously slowing down the flow. At the International Nickel test laboratory the use of chlorine for controlling these interlopers is easily tested in a battery of pipes set up for the purpose.

Sea Horse Institute

The laboratory behind Wrightsville Beach serves a sound practical purpose for a wide section of industry, since many metal companies, even those making competitive products, cooperate in these tests. From the point of view of many scientists, however, the great value of this laboratory is the stimulus it has given to the more theoretical side of marine deterioration problems.

In an informal fashion each year a meeting is held of chemists, physicists, biologists and metallurgists, whose interest is mainly the theoretical side of such things as the life of shipworms or antifouling paints. Some are concerned with the electro-chemistry of corrosion problems or the behaviour of reinforced concrete in seawater but all meet side by side with applied scientists from the industrial laboratories. Members of this stimulating group, which has become known as the "Sea Horse Institute", will examine during the annual meeting several thousand test specimens, making notes as they go, with the same gleam in their eyes as the orchid fancier loose at a flower show.

The Sea and the Machine

By HILARY B. MOORE

WHEN MACHINERY replaced hand work in textile production, in printing and in other industries, the workmen fought the introduction of the machines, fearing that they would lose their jobs. Instead, they found that the machines turned out more and cheaper products, and the widened markets called for more operators than there had been before. It is this cheapness and speed of production which we usually think of when we speak of the mechanization of industry.

Research can benefit just as much as industry from mechanization, although probably more in the speed of production than in the cost of the finished product. However, there is a third aspect of mechanization which perhaps means even more to marine research than the other two, the ability of the machine to accomplish otherwise impossible tasks. We are all familiar with the story of electronic brains. These can rapidly solve mathematical problems which might take several lifetimes of work by hand. Where a quick answer is called for, as in the flight of an ultrasonic missile, the solution could not possibly be found without the machines.

Oceanography embraces such diverse fields as chemistry, physics, biology and, in fact, almost all the sciences. Not all of these have progressed equally in mechanization, and perhaps the most exciting thing in

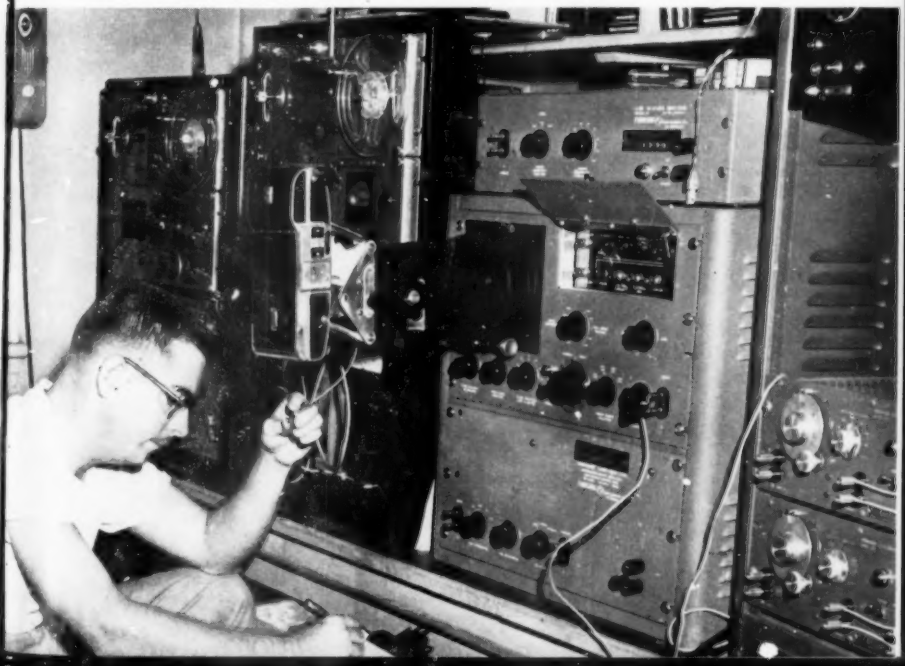
marine research is the chance of seeing its accelerated growth as modern methods are brought into use.

Charting the sea floor

When the *Challenger* explored the ocean depths for the first time, the ship was hove to, and soundings were laboriously made with a weighted rope. Only a few soundings could be made each day, so only a very patchy picture could be built up of the shape of the sea bottom. Today an ultrasonic ping echoes back from the bottom in a few seconds to give a continuous record of the depth. This is done while the ship is going full speed. The added detail this gives is letting us map submarine canyons and peaks which were never even suspected by the earlier oceanographer.

The study of sea temperatures is vital in the understanding of ocean currents. The earlier oceanographer had to stop the ship and then lower on a cable a series of delicate and expensive thermometers. The Navy needed to know temperatures in order to tell how good sonic conditions were for locating submarines. When they were chasing a submarine, they needed the information in a hurry. So the bathythermograph was developed, an instrument which could be let out from a destroyer traveling at full speed, and which when hauled back, showed a ready made graph of the temperature at different depths. True, this method is not as accurate as a thermometer, but the ease of its use has, for many purposes, made up for the loss of accuracy by the great number of observations which can be made.

The oceanographer also often needs to know the salinity of the water. Where, before, he took samples of the



FRANK STEPHENS *reading the dials of some of the modern acoustic and electronic equipment used by the present day oceanographer.*

water and sent them back to the laboratory for a chemist to analyze, he can now use an instantaneous recorder. Again it is not capable of as accurate readings as a laboratory analysis, but, towed from the ship, it plots a continuous graph of salinity, temperature and depth. For the rapid survey of an estuary where the conditions are changing rapidly with the tide, this is a tremendous advance.

Ocean Currents

Currents used to be studied with current meters, hung from an anchored ship, or by throwing overboard large numbers of drift bottles, a few of which you hoped might be recovered and returned. There is now another high speed method. The GEK, developed at Woods Hole Oceanographic Institution, has two electrodes which are towed behind the ship. The electrical potentials which these measure give a record of water current speed which is independent of the speed of the ship and thus allows measurements to be made at full speed. If the modern oceanographer needs to travel still faster, he can even fly along the edge-of the Gulf Stream and map its boundary from temperatures actually recorded on the plane. The Gulf Stream is both big and changeable, so such methods are now discovering information which it would have taken a whole fleet of ships to obtain a few years ago.

Navigation, too, has its newer methods. Radio gives exact time signals, Loran shows exact position on special charts, and radar gives shorter range fixes where visibility is bad or nil. All of these play their part in marine research.

Some of these new tools have given greater accuracy to our observations, but perhaps their greatest value lies in the speeding up of operations. There are too few oceanographers, and too few ships for their use, so the speeding up of their seagoing operations makes possible what they could not have attempted before.

The biologist and the machine

The electronic equipment of the seagoing physicist would bewilder the physical oceanographer of a generation ago. The biologist, though, would find far less change. For him, mechanization has hardly started. Bottom living animals are collected with dredges that have changed little in fifty years, and plankton is strained from the water much as it was when the first plankton nets were built. A few gadgets have been added such as gauges to metre the flow of water through the nets, and a machine that files the plankton away on a moving band of netting as it is collected on a long transect. Underwater cameras have brought back pictures of animals crawling on the abyssal bottom and television cameras are beginning to let us watch the living animals and see how our nets pursue them. We may even use sonic methods to locate the animals, recording echoes from schools of fish, and listening to the noises which fish make.

On the whole, though, the planktologist has to spend long hours towing his old-fashioned nets, knowing what a large proportion of the more active animals can avoid them, and then still longer hours identifying each individual under a microscope. The miner or geologist have automatic methods of separating desired min-

erals from the other constituents of their samples. The biologist still uses the slow method of hand picking the material. We dream of instruments which will automatically separate copepods from arrow worms and even tell us how many there are of each kind of copepod in our catch. Looking at the achievements in other fields this is surely not too much to ask, yet it sounds almost absurdly impossible to the present day worker.

Other fields of marine research have their machines which in turn have opened up new possibilities. The submarine geologists have harnessed the huge pressures at ocean depths to bring them core samples plunged far deeper into the bottom than could ever be reached by the old free-fall corers. The fishery biologist, attaching tags to fish to follow their growth and migrations, can sometimes use an electronic device to locate a single tagged individual out of a whole boat load landed at the docks. In the study of ancient oceans, radio-active techniques applied to long dead shells can now tell us rather precisely the temperature of the ancient seas in which the shells were living, and even what the summer and winter temperatures were.

Wherever we turn, new instruments are opening up the way to exploration that was beyond our horizon a generation ago. Unfortunately, these instruments themselves harness such an array of sciences that it is hard for one man to understand the working of all the machines let along the jobs they are intended to do. Marine science is so comprehensive that we are usually too specialized to know what is going on outside our own particular field. Often it is almost by accident that we hear of an instrument or a method, well known in some other branch of science, which is just what we need to solve one of our own particular problems. We are all faced with the problem of collecting and analyzing far more data than the time allows. The answer seems to lie largely in better mechanization and it is a safe forecast that the future developments in marine science will closely parallel the development of new, time-saving machines. The new marine laboratory needs electrical and electronic shops, metal lathes, instrument engines, microscopes and nets.

ACKNOWLEDGMENT

THE COVER shows granite rocks at Cape Porpoise in the Yorks, Maine. Made from Kodachrome transparency of photograph taken by Charles E. Lane.

Acknowledgment is made to the following sources of other photographs: inside front cover and pages 40, 42, Charles E. Lane; page 3, Gilbert Voss; page 5, Smithsonian Inst., Goode & Bean, 1895, Govt. Printing Office; page 7, Erl Roman; page 9, Journal of Researches into the Geology & Natural History of the various countries visited by Charles Robert Darwin, 1839, facsimile reprint by Hafner Publishing Co.; pages 10, 11, The Coral Reef Problem, William Morris Davis, American Geographical Society; page 13 George B. Kelez, U. S. Fish & Wildlife Service; page 14 Harvey R. Bullis, U. S. Fish & Wildlife Service; page 15, Rex Gary Schmidt, U. S. Fish & Wildlife Service; page 16, U. S. Fish & Wildlife Service; pages 19, 20, Lou Marron Expedition; pages 25, 26, 27 Flip Schulke, Univ. of Miami Photo Center; pages 28, 29, 49 Dave O'Berry; page 32 (top) Shell Oil Co., (bottom) Scripps Oceanographic Institute; pages 34, 35, 37, Virginia Fisheries Lab.; page 36 A. Aubrey Podine, Virginia Fisheries Lab.; page 43, Max Coan News Service; page 44, Fred Mizer; pages 46, 47 International Nickel. Back cover, Scientific American Inc.

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Concentrations of fishes off the coast of Peru attract large quantities of birds. This photograph was taken on the Yale South America Expedition, 1943. See story on Page 18.